ACTUAL AND PREDICTED PERFORMANCE OF BROILER CHICKENS

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Assignment presented in partial fulfilment of the requirements for the degree MASTER OF PHILOSOPHY IN LIVESTOCK INDUSTRY MANAGEMENT at the University of Stellenbosch.

Pectora roborant cultus recti

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DECLARATION

I, the undersigned, hereby declare that the work contained in this assignment is my own original work and that I have not previously, in its entirety or in part, submitted it at any university for a degree.

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ABSTRACT

The aim of this study was to evaluate the performance and profitability of different dietary specifications for broiler chickens slaughtered at 35 days of age. Two trials were performed to evaluate different production parameters. The results of these trials were compared to the predicted results of the EFG broiler model. No carcass data were available for the two trials mentioned above. Therefore, in order to evaluate the accuracy of the broiler model when predicting carcass characteristics, two published data sets (Leeson *et al.,* 1996a) were used. Predicted and actual values were compared, evaluated and discussed.

Two broiler trials were performed. In Trial One the amino acid density decreased throughout the range of three treatments from prestarter to finisher diets. In Trial Two the amino acid density decreased only in the four finisher diets. The main difference between predicted and actual results was the response to body weight. The model predicted a steady increase in feed intake to compensate for the lower dietary specifications while body weight did not change significantly. This increase in feed intake seems to be enough to maintain body weight. Trial birds also increased their feed intake as dietary amino acid density decreased, but this compensation seemed to be too low to maintain body weight compared to the control diet. The birds may find it easier to compensate when they have time to adapt to the specification.

There is evidence in the literature that birds need seven days to adapt their feed intake to a lower feed specification (Leeson *et al.*, 1996a). It can be speculated that the trial birds started to loose body weight due to a lower amino acid intake in this period. The model seems to adapt feed intake immediately after a change in diet specification.

The simulation on literature data lead to the following conclusions:

1) Broilers posses the capacity to increase their feed intake with at least 65% should finisher diets with lower amino acid and energy concentrations be supplied. If only the energy concentration of finisher diets were decreased, the increase in feed intake will be around 30%. (see Table 16 and 23)
2) The accurate prediction of feed intake from the given dietary specification has a major influence on the accuracy of the prediction of broiler performance.
3) Amino acid density and DLys:ME ratio plays a significant role in the control and prediction of feed intake.

The EFG broiler model is based on sound scientific principles. The model is comprehensive and can be used for a wide range of environmental and management conditions as well as dietary conditions. The nutritionist can use the model with confidence to assist in practical feed formulation. The actual strength of the model lies in the time and money being saved compared to practical trials.

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OPSOMMING

Die doel van hierdie studie is om die prestasie en winsgewendheid van braaikuikens te bepaal wanneer voere met verskillende digthede tot op 35 dae gevoer word. Twee eksperimente is uitgevoer om produksie-resultate te evalueer. Die resultate van hierdie eksperimente is met die voorspelde waardes uit die EFG simulasie-model vergelyk. Aangesien geen karkasdata vir bogenoemde eksperimente beskikbaar was nie, is twee gepubliseerde datastelle gebruik om hierdie deel van die model te evalueer (Leeson *et al.,* 1996a).

Twee braaikuiken eksperimente is uitgevoer. Eksperiment Een het uit drie behandelings bestaan waarvan die aminosuur-konsentrasie vanaf dag een tussen behandelings verskil het. In Eksperiment Twee het die aminosuur-konsentrasie net in die vier afrondingsdiëte verskil. Liggaamsmassa op 35 dae het die grooste verskil tussen voorspelde- en werklike waardes getoon. Beide voorspelde en werklike innames het in albei eksperimente verhoog soos wat aminosuur-konsentrasie afgeneem het. Voorspelde liggaamsmassa het egter konstant gebly terwyl werklike data 'n afname in liggaamsmassa getoon het. Dit bleik dat die voorspelde toename in innames voldoende was om massa te onderhou terwyl die voëls in werklikheid nie genoeg gekompenseer het nie. Leeson *et al.,* 1996a het tot die gevolgtrekking gekom dat braaikuikens minstens sewe dae benodig om hul voeriname by 'n nuwe spesifikasie aan te pas. So 'n stadige aanpassing kan daartoe lei dat energie- en aminosuur-inname daal indien 'n dieet met laer spesifikasie gevoer. Dit sal daartoe lei dat die kuikens liggaamsmassa verloor.

Uit die literatuur simulasies is die volgende afleidings gemaak:

1) Braaikuikens besit die vermoeë om voerinname in die afrondingstyd met minstens 65% te verhoog indien 'n afrondingvoer met laer amiosuur- asook energiekonsentrasie gevoer word. Indien net die energiekonsentrasie verlaag word, sal die inname met sowat 30% verhoog.
2) Die akkurate voorspelling van inname is krities vir die akkurate voorspelling van produksie-parameters.
3) Aminosuur-digtheid en DLys:ME speel 'n belangrike rol in die beheer en voorspelling van voerinname by braaikuikens.

Die EFG braaikuikenmodel is op suiwer wetenskaplike beginsels geskoei. Die model is omvattend en kan vir 'n wye reeks van omgewings- en bestuurstoestande asook dieet-spesifikasies gebruik word. Die voedingkundige kan die model met vertroue gebruik om met praktiese voerformulering by te staan. Die model kan die formuleerder baie tyd spaar aangesien praktiese eksperimente ingeperk kan word.

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LIST OF ABBREVIATIONS

AME_n	Apparent metabolizable energy, corrected for nitrogen excretion
Arg	Arginine
Corboh.	Carbohydrate
CP	Crude protein
d	Days
DFI	Desired feed intakes
EEC	Effective energy content
EER	Effective energy requirement
FCR	Feed conversion ratio (kg feed / kg live weight)
FP	Predicted feather protein
g	Gram / grams
Kcal	Kilocalories
Lys	Lysine
MJ	Mega joules
P	Predicted feather-free body protein
PEF	Production efficiency factor: [(Liveability as percentage*live weight in kg*100) / (FCR*age in days)]
(T)SAA	(Total) sulphur containing amino acids, i.e. methionine plus cystein
W	Weight

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1. INTRODUCTION

The aim of this study was to evaluate the performance and profitability of different dietary specifications for broiler chickens slaughtered at 35 days of age. Two trials were conducted to evaluate body weight gain, feed intake and feed conversion ratio (FCR). The production efficiency factor (PEF) was also calculated for all treatments. The first trial consisted of three dietary treatments with a step-down amino acid content throughout the range of pre-starter to finisher diets. The second trial consisted of four dietary treatments with a step-down amino acid content in the finisher diets only. The results of these trials were compared to the predicted results of the EFG broiler model (EFG broiler growth model, 1999). No carcass data were available for the two trials mentioned above. Therefore, in order to evaluate the accuracy of the broiler model when predicting carcass characteristics, two published data sets (Leeson *et al.,* 1996a) were included. Predicted and actual values were compared, evaluated and discussed.

The aim of this study is:

1) To evaluate the performance and profitability of different dietary specifications for broiler chickens slaughtered at 35 days of age.
2) To compare the commercial and economic data from these trials to the values predicted by the EFG broiler model.
3) To evaluate the values predicted by the EFG broiler model to published growth and carcass characteristic data.

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2. LITERATUREATURE STUDY

2.1 A GROWTH SIMULATION MODEL FOR POULTRY

The EFG broiler model (EFG, 1999), developed by Emmans, Fisher and Gous, is used to simulated the growth of broiler chickens. The feed composition, feeding programme, feed price, genetic parameters, management factors and economic parameters are all used as inputs for the simulation. After running the simulation, the user gets a complete output with production and carcass data as well as an economic evaluation.

The principles used in the model to simulate growth are given in the following paragraphs (EFG, 1999):

Each growing bird has an inherent potential growth rate that can be measured in an ideal or non-limiting environment. The bird has a 'purpose', namely to achieve its potential and therefore to reach maturity in the shortest possible time. Using this theory it is possible to describe the potential growth rate and hence determine the nutrient requirements for potential growth of different genotypes. It is possible, in addition, to determine to what extent the bird will be successful in achieving its potential when kept in a limiting environment and when given an imbalanced food.

The chemical and physical composition of the body changes systematically during growth, so a single growth function would not be sufficient to describe the changes in composition as growth proceeds. By predicting the growth of protein in the body by means of a growth function and then relating the growth of water, ash and lipid to this, it is possible to determine the rate of growth of the whole body. There are strict relationships between the weights of the components in potential growth that can be used for this purpose. The first step in describing a genotype, then, is to determine the potential rate of protein gain, which can be accomplished by means of a Gompertz growth curve (EFG, 1999).

The Gompertz growth equation has the following form:

$$Wt = A \cdot \exp(-\exp(-B(t - t^*)))$$

where the weight of the bird at time t, (Wt), is expressed in terms of A, the weight at which the growth rate becomes zero, i.e. the mature weight of the bird; B, the rate parameter, or rate of maturing; t*, the time at which the growth rate is at its maximum. An advantage of this equation is that the parameters of the equation can be interpreted in terms of the biology of the bird.

The growth rate of the bird at time t can be calculated from the derivative of the above equation, namely:

$$dW/dt = B \cdot W \cdot \ln(A/W)$$

As the empty body consists of water, lipid and the remainder (lipid-free dry matter), a separate equation could be fitted to each component in turn. There is good evidence to suggest that the lipid-free dry matter (protein plus ash) is of constant composition and that the growth rate parameters (B) for each component are the same for a given genotype. This means that the ash component of the carcass can be predicted directly from the protein content, using the isometric relationship that exists between them, and that water and lipid weights, which are related to the lipid-free dry matter weight of the carcass by a simple power function, can be predicted from the protein weight, under non-limiting conditions, by allometry. In order to calculate the allometric relationship between the protein and lipid, which will differ between individuals and between

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genotypes, estimates of the lipid-to-protein ratio at maturity and the allometric parameter for lipid are required, which have to be determined under non-limiting conditions.

Given the growth rate of the remainder (protein plus ash) and the allometric relationship between both water and lipid and the remainder, the growth rate of the empty body can be seen as the sum of the growth rates of the components, which can be estimated with a high degree of accuracy for birds kept under non-limiting conditions.

Feathers make up a substantial proportion of the total body protein, and because the amino acid composition of feathers differs markedly from that of non-feather protein, it is necessary to predict the growth of both feather protein and of non-feather protein so that the nutrients required for the production of these components can be calculated.

Barnard (1990) summarised the following information regarding the modelling of broiler results:

2.1.1 Steps for simulation modelling

The following steps have been outlined by Fisher (1987 and 1988, quoted by Barnard, 1990), in order to simulate the growth of chicken and thus permit the calculation of amino acid requirements during the entire growing period:

a) Predict feather-free body protein (P) growth, using a Gompertz growth curve.
b) Predict feather protein (FP) growth over time.
c) Predict water, fat and ash from their allometry with empty body protein, by defining body composition at day-old and maturity.
d) Predict maintenance protein requirements, scaled to mature body protein (P_m), from body protein weight (P).
e) Calculate effective energy content (EEC) of a feed from AME_n by making corrections for digestible protein content, digestible lipid content and indigestible organic matter.
f) Calculate effective energy requirement (EER) from maintenance energy (scaled to P_m), protein (P + FP) and lipid gains.
g) Make the necessary assumptions regarding the utilisation of dietary lipid for lipid growth.
h) Calculate amino acid deposition in P and FP from appropriate tissue composition data.
i) Convert this amino acid deposition in P and FP into dietary amino acids by dividing by a single coefficient of utilisation. This result plus the maintenance requirements, represents the total amino acid requirement.
j) Convert effective energy requirement (EER) to desired feed intakes (DFI) and calculate amino acid requirements (mg/bird day).

For the prediction of growth, body composition and food intake certain assumptions have to be made (Emmans, 1981 and 1988, quoted by Barnard, 1990):

a) A bird has a potential lipid-free growth rate that it seeks to attain, comprising protein, water and ash.
b) It endeavours to obtain a minimum level of fatness, fat growth then being the deposition of lipid above this minimum level.
c) Both potential growth rate and the level of fatness are dependent on the genotype and stage of maturity (u).
d) In order to achieve its potential growth rate and fatness an animal has to rely on its environment for the necessary resources.

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From the above it is obvious that in measuring the potential growth rate and inherent fatness of a bird, the bird has to be reared in an unrestricted, disease-free environment and receive an optimally balanced diet.

2.1.1.1 Feather-free body protein growth

According to Emmans & Fisher (1986), quoted by Barnard (1990), there are three potential ways of predicting growth rates:

a) predict the growth of the empty body weight as a whole;
b) predict the growth of protein, lipid, water and ash components separately; or
c) predict one component only (body protein) and consider the other three components as allometrically related to this base component.

As recommended by Emmans & Fisher (1986), quoted by Barnard (1990), the latter option was used in predicting growth, using body protein as the base component. The Gompertz function is recommended as a means of defining protein growth (P) (Fisher, 1980; Emmans, 1981 and Emmans & Fisher, 1986, as quoted by Barnard, 1990).

The derivative of this function can be used to describe the potential growth rate of body protein in terms of a state variable or degree of maturity, u, and two inherent characteristics, a rate parameter, B (per day) and mature size parameter, P_m (kg) as follows:

$$DP/dt + P_m.B.u.\ln(1/u) \text{ (kg)}$$

where:

P_m = feather-free body protein weight at maturity (kg)
B = 1/k, a growth constant
u = P/P_m = degree of maturity
P = $u.P_m$ = feather-free body protein weight at time, t (kg)
ln = natural logarithm

From the above equation the body protein content at any age can be determined as follows:

$$Bprt = Pm.e[-e(\ln(-\ln(uo)) - B.t) \text{ (kg)}$$

where:

Bprt = body protein weight (kg) at time t
t = age (d)
uo = Po/Pm
Po = Protein weight at hatching.

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2.1.1.2 Feather protein

There are difficulties in predicting feather growth, the reasons for which are as follows (Fisher, 1988 and Emmans, 1988), as quoted by Barnard (1990):

a) Feather weight is not a simple power function of body weight, as no constant allometric relationship exists between P and FP.
b) Feather weight at slaughter is not a true reflection of actual feather growth, because of a continuous process of feather shedding.
c) There are genetic differences in the rates of feather growth.

The Gompertz function can, however, be used to predict feather protein growth rate [dFP/dt].

2.1.1.3 Empty body weight

Empty body weight can be defined as plucked body weight minus gut fill, the former being made up by protein, lipid, water and ash and a small amount of carbohydrate (Emmans & Fisher, 1986, quoted by Barnard, 1990). It is common knowledge that the composition of empty body weight changes with age, and the following observations have been made in this regard (Emmans, 1981 and Emmans & Fisher, 1986, quoted by Barnard, 1990):

a) the amino acid composition of the dry matter (lipid free) changes systematically with time;
b) the water content of the empty body (lipid free) changes systematically with time; and
c) the lipid content of the empty body invariably increases with time.

It is also well established that the growth of the other body components can be predicted from their allometric relationship with body protein (Emmans & Fisher, 1986; Fisher, 1987 and Emmans, 1988, quoted by Barnard, 1990). The component weight at maturity, C_m is expressed as a ratio to P_m, so that

$$CPRm = Cm/Pm$$

The component growth rate (dC/dt) can be predicted by

$$dC/dt = (dC/dP)\ (dP/dt)$$

where:

dC/dt = lipid, moisture and ash growth rate (kg/d)
dP/dt = empty body protein growth rate
dC/dP = the relationship between the components (lipid, water and ash) and protein weight.

The growth rate of empty body weight (dEW/dt) is then obtained from the sum of the growth rates of the four components (protein, lipid, water and ash):

$$DEW/dt = \{P_m.B.1n(l/u).u.\}\ \{1 + (z.u^c)_l + (z.u^c)_w + (z.u^c)_a\}\ \ (kg/d)$$

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2.1.1.4 Maintenance protein

Maintenance can be defined as the ability of an animal to remain in an unchanged state (Brody, 1945, quoted by Barnard,1990). Nutrients are nevertheless required to maintain the body in that state. To quantify this nutrient supply, maintenance protein requirements (MP) are based on a maintenance scaling rule (Emmans & Fisher, 1986 and Emmans, 1988, quoted by Barnard, 1990) as follows:

$$MP = M_p . P_m^{0,73} . u \quad (g/d)$$

where:

M_p = 8g/kg, the maintenance requirement per maintenance unit.

Maintenance protein requirements are therefore based on the present state of body protein maturity (u) of an animal and on its genotype accomplished by incorporating potential mature body protein weight (Pm) into the equation.

2.1.1.5 Effective energy and food intakes

The equations used to define energy requirements and subsequently food intakes are derived from an effective energy system proposed by Emmans (1984), quoted by Barnard (1990). Effective energy of a diet can be described as the metabolizable energy content of a diet less heat production due to defecation, fermentation and potential excretion, resulting from feed being consumed (Emmans, 1984, quoted by Barnard, 1990). The effective energy content (EEC) of a feed can be described by the following simplified equation (Emmans, 1988; see also Emmans & Fisher, 1986, quoted by Barnard, 1990):

$$EEC = AME\,n - z1\,DPC - z2FOMC + xz3DLC \quad (MJ/kg)$$

where:

AMEn = apparent metabolizable energy corrected for zero N-correction (MJ/kg)

DPC = digestible protein content (g/kg)

FOMC = faecal (undigested) organic matter content (g/kg)

DLC = digestible fat content (g/kg)

z1 = 4,67, heat produced for N excretion and retention (MJ/kg)

z2 = 3,8, heat produced for eating indigestible organic matter, yielding no energy (MJ/kg)

z3 = 12,0, improvement in ME utilisation from digested dietary lipid
(x = the proportion of digested lipid directly retained, assumed to be = 0,5).

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A growing bird, in a thermally neutral environment, needs effective energy for maintenance, protein and lipid retention. The effective energy requirement (EER) of a bird is defined by (Emmans, 1988, quoted by Barnard, 1990) as:

EER = MH + 50dP/dt + 56dL/dt (MJ/d)

where:

MH = 1,63Pm^0,73, the maintenance heat (MJ/d)

dP/dt = rate of protein (FP and P) retention (kg/d)

dL/dt = rate of lipid retention (kg/d) (see Emmans, 1988 and Fisher, 1988, quoted by Barnard, 1990, for more detail).

The desired food intake (DFI) of a bird, which is the amount of feed a bird needs to eat to attain its potential growth rate (Emmans, 1981, quoted by Barnard, 1990), can then be calculated as (Emmans, 1988, quoted by Barnard, 1990):

DFI = EER/EEC (kg/d)

It is important to recognise that a bird will fail to consume this amount of feed when:

a) it is too hot (not in a thermally neutral environment);
b) the feed is too bulky;
c) the feed is unbalanced; or
d) some or other toxin is present in the feed (Emmans, 1981, quoted by Barnard,1990).

2.1.1.6 Amino acid requirements

The amino acid requirements can be calculated for the predicted potential protein growth rates (P + FP) and maintenance protein needs. The equation for this calculation is based on that of the ARC (1981), as quoted by Barnard, (1990) and is as follows:

AAR = [a (dP/dt) + b(dF/dt) + cMP] /Ec (g/d)

where:

AAR = amino acid requirements (g/d)
a = amino acid coefficient for body protein (g/kg protein)
b = amino acid coefficient for feather protein (g/kg protein)
c = amino acid coefficient for maintenance (g/kg)
Ec = an efficiency coefficient for amino acid utilisation.

Since body and feather protein have different amino acid compositions, it is recommended that these proteins should be considered separately in the above calculation (Emmans & Fisher, 1986 and Fisher, 1987, quoted by Barnard, 1990). As the amino acid requirements for maintenance are not properly defined, it is assumed that this composition is similar to that of body protein (Emmans, 1988, quoted by Barnard, 1990). An inefficiency exists when dietary amino acids are utilised for growth and maintenance. Fisher (1987)

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as quoted by Barnard (1990), recommended that a single fixed coefficient of amino acid utilisation should be used to calculate these amino acid depositions. In doing this, it has to be assumed that amino acid utilisation is independent of the type of amino acid and dietary concentration, age of the bird and genotype (Fisher, 1987, quoted by Barnard, 1990).

2.2 DIETARY DENSITY AND ENVIRONMENTAL FACTORS INFLUENCING PREDICTION OF BROILER PERFORMANCE – A LITERATURE REVIEW

From the literature review, it can be seen that performance of broiler chickens is influenced by factors such as protein and energy density, amino acid ratios, the protein:energy ratio, environmental temperature and feed intake. These factors can be measured relatively accurately. Some factors, however, seem to be more difficult to measure and incorporate into models, e.g. daily temperature variation, disease challenge, anti-nutrient factors, imbalanced diets, mycotoxins and the possible change in ideal amino acid ratios due to heat stress.

The aim of this part of the literature study is to describe the influence of some of these factors on broiler performance, as they are relevant to an understanding of the response of broilers to these treatments and how these variables can be modelled.

2.2.1 Ideal amino acid ratios

The principles of the ideal amino-acid ratios were used when formulating diets for trials presented in the following chapters. Baker & Han (1994) stated that a multitude of dietary factors (e.g. protein level, energy level and feed intake), environmental factors (e.g. disease, crowding, feeder space and heat stress) and genetic factors (e.g. sex and capacity for lean vs. fat growth) may affect amino acid requirements, but the ideal ratio of indispensable amino acid to lysine (Lys) should remain largely unaffected by these variables. Hence, one can place emphasis on establishing accurate lysine requirements under a variety of circumstances, after which the remaining indispensable amino acid requirements can be calculated. Lysine is selected as the reference amino acid for three primary reasons: Firstly, its analysis in feedstuffs, unlike tryptophan and sulphur amino acids (SAA), is relatively simple and straightforward. In the second place, a considerable body of data exists for digestible lysine needs of poultry. Finally, absorbed lysine is used only for protein accretion.

According to these authors, the ideal amino acid ratios (true, digestible basis) for the early growth phase (8 to 22 days) of broiler chicks are: lysine, 100%; methionine + cystine, 72%; threonine, 67%; valine, 77%; arginine, 105%; histidine, 32%; isoleucine, 67%; tryptophan, 16%; leucine, 109%; phenylalanine + tyrosine, 105%; glycine (or serine), 65%; and proline 44%.

Mack *et al.,* (1999) suggested the following profile in relation to lysine for chickens between 20 and 40 days of age: Lysine 100%; methionine + cystine, 75%; threonine, 63%; tryptophan 19%; arginine, 112%; isoleusine, 71% and valine 81%.

The benefit of the ideal amino acid ratios is that once a ratio is established for a certain age period, one can concentrate on accurately determining the lysine requirement under a variety of conditions and then calculate the requirement for all other amino acids under this condition based on the lysine requirement and ideal ratios. Formulating diets according to this concept allows for the most efficient and economical use of dietary protein by maximising nitrogen utilisation and minimising nitrogen excretion. Despite the obvious advantages of working with an ideal amino acid profile it has to be noted that it does not account for effects of amino acid interactions such as that between lysine and arginine.

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Typically, European broiler diets are kept at a constant composition for periods of two to three weeks. Consequently, under these conditions the ideal amino acid ratio in the diet is an approximation to the ever-changing optimum amino acid ratio required by the bird. It might, therefore, be beneficial to move towards feeding five or six different diets between hatching and slaughter.

2.2.2 Arginine and lysine

Brake *et al.,* (1998) reported that chick weight gain is depressed by a diet high in lysine. This effect was subsequently reported to result from an antagonism that could be corrected by the addition of arginine to the diet.

High environmental temperature after the brooding period decreases food intake and growth of broilers. Recommendations to offset this response to heat stress include decreasing the dietary crude protein and supplementing the diet with essential amino acids. It is tempting to consider the possibility that the ideal amino acid ratio might be altered during heat stress.

Previous research showed that the requirement of broilers for methionine was less at high than at thermo-neutral temperatures. This implies that the ideal amino acid balance for broilers varies with ambient temperature. Digestibility of arginine in diets could be significantly decreased or increased at an ambient temperature of 30°C when compared to 18°C or 21°C, respectively. Heat stress might alter gut absorption of arginine and, thereby, plasma amino acid balance.

Growth studies showed that increasing the Arg:Lys ratio at high temperatures produced consistent improvements in food conversion without any loss in growth. Although increasing dietary sodium chloride concentration reduced the Arg:Lys ratio necessary for optimum food conversion, results indicate that the ideal amino acid balance for broilers varies with ambient temperature.

Mendes *et al.,* (1997) also reported that an increased Arg:Lys ratio at high temperatures (33.3°C) improved feed conversion and dressing percentage and reduced abdominal fat content. The benefit seems to be limited to feed conversion only, as increasing lysine levels or Arg:Lys ratios did not improve weight gain, increase breast meat yield, or attenuate adverse effects due to heat or cold exposure, it is concluded that the levels of lysine and arginine suggested for 21 to 42 days by the National Research Council (1994) are adequate for birds of this age under the environmental conditions encountered.

The influence of environmental conditions on amino acid requirements needs further investigation in order to bring it into account when modelling broiler results.

2.2.3 Amino acid requirements and profit

Reliable information on amino acid digestibility of feedstuffs, maintenance amino acid requirements, whole-body amino acid accretion rates and efficiencies of amino acid utilisation above maintenance are necessary to model amino acid requirements in animals and to predict profitability accordingly (Edwards *et al.,* 1999). Schutte & Pack (1995) also emphasised that dietary amino acid specifications for broilers should be adjusted to reflect processing and marketing conditions. This reflects the idea that formulation of broiler diets should ideally maximise profitability, which may not necessarily coincide with maximum bird performance.

Schutte & Pack (1995) performed two growth trials to measure the effects of dietary methionine and cystine (SAA) on growth rate, food conversion efficiency and breast meat deposition in male broilers. Significant responses in weight gain, efficiency of food conversion and breast meat percentage were detected, which could be described well by exponential regression curves. Dietary SAA requirements to obtain

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maximum efficiency of food utilisation and maximum breast meat deposition were estimated to be about 9.0 g/kg from 15 to 33 days of age, and about 8.0 g/kg from 33 to 43 days of age.

In both trials, the dietary optimum of SAA was found to be higher for birds to be processed further than for birds to be marketed as whole carcasses. Schutte and Pack (1995) concluded that in broilers grown to 1.7 kg, 8.7 g SAA/kg feed maximised profit when only the effects on FCR were taken into account, while 9.6 g/kg would optimise profit should a premium be paid for an increased breast meat portion. (see Figure 3)

Figure 1, 2 and 3 show the effect of SAA concentration on food conversion efficiency, breast meat as percentage of carcass and profit.

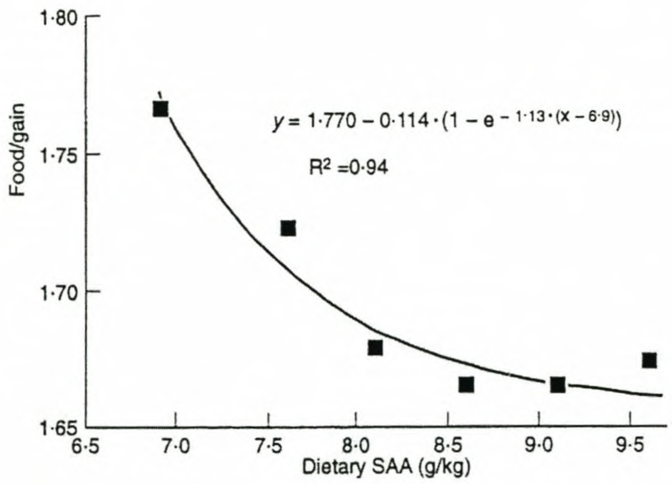

Figure 1 Feed conversion efficiency (feed:gain) response to increased dietary SAA in broiler chicks between 15-33 days of age (Schutte & Pack, 1995)

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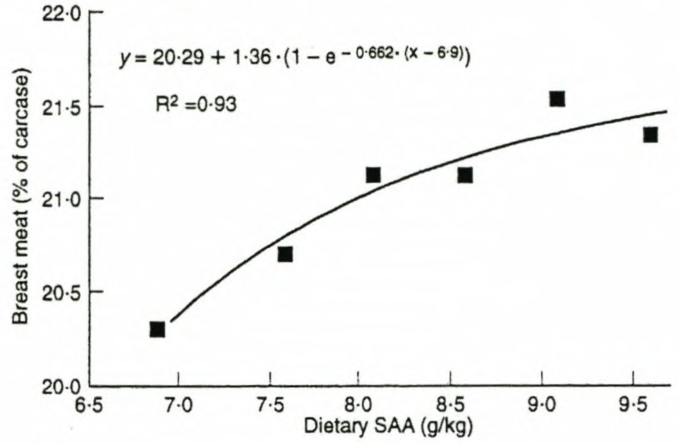

Figure 2 Breast meat (as % of carcass) response to increased dietary SAA (g/kg) in broiler chicks between 15-33 days of age (Schutte and Pack, 1995)

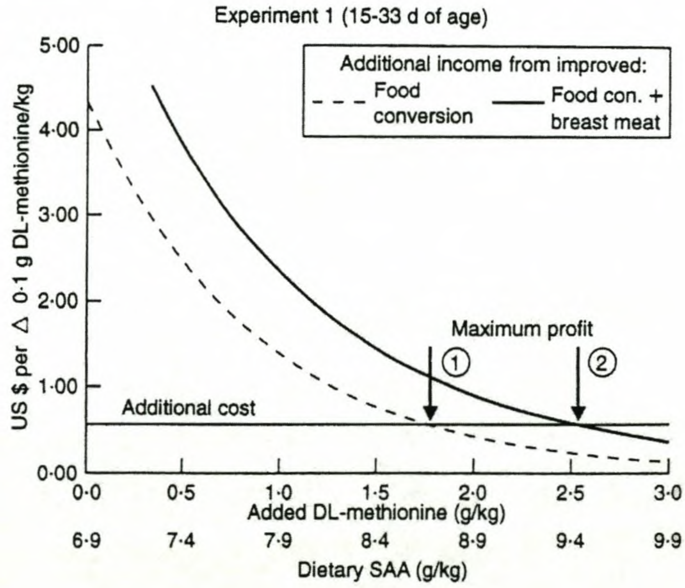

Figure 3 Optimum addition of DL-methionine as calculated from comparison of marginal income and marginal cost per increment in DL-methionine of 0.1 g/kg (Schutte and Pack, 1995)

------ Optimum addition of DL-methionine if only food conversion efficiency response is evaluated

____ Optimum addition of DL-methionine if food conversion efficiency and breast meat responses are evaluated

where 1 = 8.7 g SAA / kg feed and 2 = 9.6 g SAA / kg feed (as is).

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Pack & Schutte (1995) found that under European price conditions, a dietary level of 9.5 g SAA/kg feed was most profitable for broilers grown to 1.7 kg. In broilers grown to 2.2 kg two situations were simulated. If only the feed conversion response was evaluated, the most profitable total SAA level would be 8.5g/kg. If both feed conversion and breast meat responses were considered, a higher level of 0.89% TSAA would be optimum.

2.2.4 Nutrient density, feed intake, carcass composition and temperature

The crude protein and amino acid status of a diet influences the carcass composition of broilers, with increased carcass protein and reduced carcass fat accompanying increases in dietary protein or essential amino acid content. Breast meat development is sensitive to dietary lysine content, as muscle protein is high in lysine and the contribution of breast muscle to total carcass meat is considerable. Breast meat contributes about 30% of total carcass meat and as much as 50% of total edible carcass protein (Si *et al.,* 2001).

Body weight is maximised at lower levels of essential amino acids, than is feed conversion. Broilers fed diets marginal in amino acids will over-consume to meet their requirements for gain, thus resulting in increased carcass fat content with reduced feed conversion. Increasing dietary lysine levels cause an increase in broiler carcass protein retention and a decrease in fat retention (Si *et al.,* 2001).

The results from three trials (Trial 1-3) completed by Sklan & Plavnik (2002) show how nutrient density can influence broiler response. In order to clarify the effect of crude protein on performance, this study examined the growth responses to diets with different energies to either constant concentrations of some essential amino acids but differing crude protein contents or to diets with constant essential amino acid:CP ratios.

Increasing crude protein resulted in a linear decrease in feed intake while weight gain and feed efficiency changed quadratically with a smaller positive effect at the highest crude protein intakes. Feed intake decreased and feed efficiency increased with higher dietary energy and interactions between protein and energy were significant. Abdominal fat content and the efficiency of protein retention decreased with increasing dietary protein intake.

Using constant essential amino acid:crude protein ratios at increasing crude protein intakes resulted in feed intake, weight gain and feed efficiency all increasing before reaching a plateau. Abdominal fat decreased with protein intake and the efficiency of protein retention was quadratic, decreasing at the higher protein intakes.

It is proposed that broiler performance at the lower protein intakes was limited by either nonessential amino acid (Trials 1 and 2) or essential amino acid (Trial 3) intake, whereas at high protein intakes the decreased efficiency of amino acid utilisation after growth requirements are fulfilled resulted in poorer performance.

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Figure 4 shows the effect of dietary protein percentage on abdominal fat.

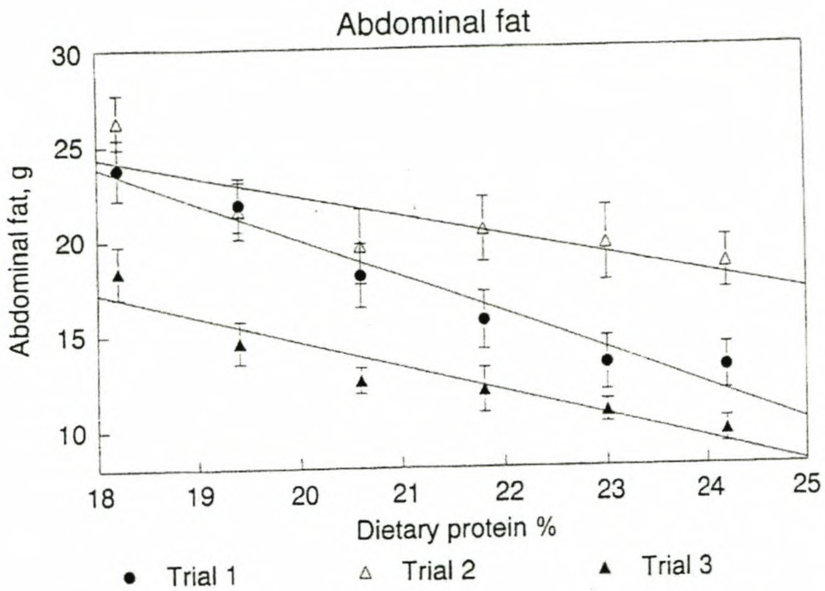

Figure 4 The negative response of abdominal fat (g) in birds fed increased levels of crude protein in three trials (Sklan & Plavnik 2002)

Trial 1: The performance of 1-4 week old Cobb broilers fed diets with constant concentrations of Lys (11 g/kg) and of SAA (9 g/kg) but with protein concentrations increasing from 182 to 242 g/kg at 12.96 MJ/kg

Trial 2: The performance of 1-4 week old Cobb broilers fed diets with constant concentrations of Lys (11 g/kg) and of SAA (9 g/kg) but with protein concentrations increasing from 182 to 242 g/kg at 13.38 MJ/kg

Trial 3: The performance of 1-4 week old Cobb broilers fed diets with constant ratios of Lys and of SAA to protein levels of 182 to 242 g/kg at 12.96 MJ/kg.

Means and SD of each treatment are shown in the graph and regression equations were calculated using all replicates. Trial 1 is indicated by filled circles, Trial 2 by open triangles and Trial 3 by filled triangles.

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Figure 5 shows how efficiency of protein retention decreases with higher CP levels.

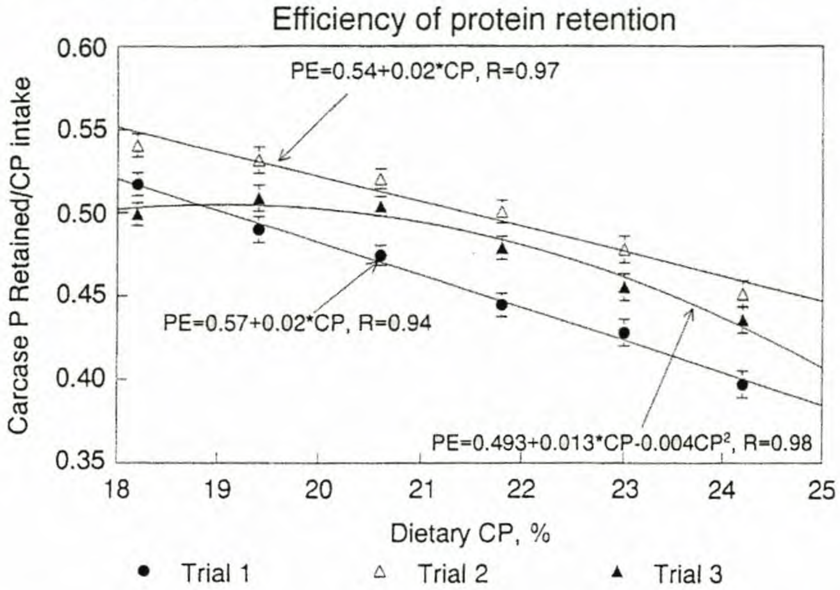

Figure 5 Decreased efficiency of protein retention (carcass protein accretion/crude protein intake) with an increase in CP in three trials (Sklan & Plavnik 2002)
Means and SD of each treatment are shown in the graph and PE is protein efficiency. Trial 1 is indicated by filled circles, Trial 2 by open triangles and Trial 3 by filled triangles.

The objective of a study performed by Si *et al.,* (2001) was to examine the relationship of the level of dietary lysine to that of other essential amino acid in diets for growing broilers. Various levels of lysine were examined with different concentrations of other essential amino acid in diets fed to male broilers grown to 56 days for further processing. In contrast to other research results dietary lysine levels had no significant effects on dressing percentage, breast meat yield or abdominal fat content. The level of other essential amino acid significantly influenced dressed yield but had no significant influence on carcass yield.

Noy & Sklan (2002) examined the effects of feeding chicks differing levels of macro-nutrients on performance during the first 7 days post-hatch in this study. With increasing protein and fat levels, feed intake and BW decreased. Fat and protein percentages in the carcass in all experiments were not altered by dietary treatments and thus the efficiency of protein and fat retention decreased with increasing dietary intake. This study indicates that feeding diets with varying macro-nutrient levels to chicks during the first week post-hatch has distinct effects as compared to older broilers. It appears that once limited amino acids and energy are provided the influence of dietary composition on immediate post-hatch growth is limited.

Emmert *et al.,* (2000) demonstrated the effect of imbalanced amino acid and temperature on bird performance. Chicks fed on graded levels of soya bean meal containing supplemental methionine and threonine (balanced diet) accreted whole-body protein more efficiently ($P < 0.05$) than those receiving graded levels of un-supplemented soya bean meal (deficient diet) and superior ($P < 0.05$) growth performance was also obtained at lower CP levels when chicks were fed on the balanced diets.

Voluntary food intake increased between 30 and 220 g CP/kg in chicks fed on deficient diets, whereas food intake of chicks fed on balanced diets increased only between 30 and 100 g CP/kg, after which it decreased between 100 and 220 g CP/kg. Protein efficiency ratio (g gain per g protein intake) decreased with each

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incremental increase in CP between 30 and 260 g CP/kg, regardless of whether diets were balanced or deficient.

Alleman & Leclercq (1997) investigated the effect of protein density and temperature on broiler performance. At 22°C, a reduced CP content did not affect growth rate and breast muscle but slightly increased adiposity and food-to-gain ratio (FCR). Water consumption was reduced. High temperature reduced growth rate and absolute and proportional breast muscle weight, and increased adiposity and FCR. These effects were more pronounced with the low CP diet. Water consumption was again reduced.

It was concluded that reducing CP content did not seem a good way to help broilers to withstand hot conditions. This experiment suggests that amino acids other than lysine, methionine and cystine are probably involved in the detrimental effect of high temperature.

Rose & Uddin (1997) demonstrated how temperature can influence growth rate at different levels of lysine concentration. A series of three diets were compared. These diets varied only in their crude protein content (140, 180 and 220 g/kg). Four lysine concentrations 32, 55, 78 and 102 g/kg crude protein) were given at each of the three protein concentrations. All the diets contained 12.7 MJ ME/kg. The authors stated that their study confirmed the data of Morris *et al.,* (1987) that the balance of lysine within the crude protein supply is an important variable that affects growth and food conversion efficiency in broiler chickens. Figure 5 clearly illustrates that weight gain decreases again as the Lys:CP increases. The relative small change in growth at high temperature (30°C) indicates that deviation from the optimum lysine concentration is economically less important at high temperatures.

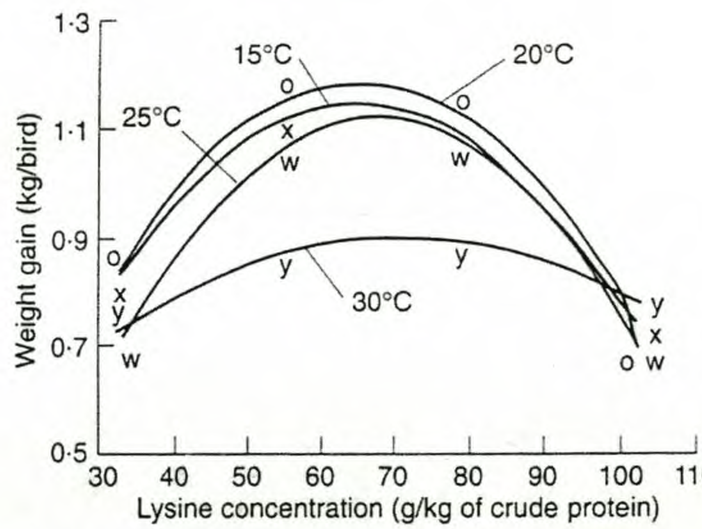

Figure 6 Interaction of temperature (15, 20, 25 and 30°C) on the growth of chickens fed diets with different lysine-to-protein concentrations (32, 55, 78, 102 g/kg crude protein) (Rose and Uddin 1997) (SED = 0.1157). The letters x,o,w, and y help to identify the response curves used for 15, 20, 25 and 30C° respectively.

According to Leeson *et al.,* (1996a) dilution of only energy resulted in a linear ($P < 0.01$) reduction in body weight at 42 days, although there was growth compensation after this time to the extent that all birds weighed the same at 49 days. Diet energy dilution resulted in increased feed intake, although energy intake was not maintained ($P < 0.01$). Diet energy dilution generally had little effect on carcass weight or yield of breast meat, although there was less abdominal fat ($P < 0.01$). Dilution of both energy and protein had a

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comparable effect on growth rate. There was a linear decrease in carcass weight and breast meat yield as the diet was diluted. These results suggest that the male broiler chicken can grow quite well on very low energy diets but that a period of at least 7 days is required for adjustment to feed intake. Even with compensatory increase in feed intake, however, the bird is unable to maintain its energy intake when fed such diluted diets.

In another experiment, Leeson *et al.,* (1996b) reported that providing diets of 2,700 to 3,300 kcal ME/kg for *ad libitum* consumption had no effect on growth rate ($P < 0.05$) and energy intake was constant; however, reducing the energy level of the diet did result in reduced carcass fatness ($P < 0.01$). When broilers were offered a choice of diets, they showed remarkably precise control of intake, such that energy intake was again constant across all treatments. However, even though energy intake was constant, broilers consuming the choice diets with the lower energy content, tended to have less carcass fat.

2.2.5 Conclusion from Leeson's trials

It was concluded that the broiler still possesses a good ability to control its feed intake based on the desire to normalise energy intake. As energy intake is decreased, or where there is increased protein intake, the bird deposits less carcass fat.

3. BROILER TRIAL ONE

3.1 THE INFLUENCE OF THREE AMINO ACID DENSITIES FROM PRE-STARTER TO FINISHER DIETS ON BROILER PERFORMANCE

3.1.1 Goal

The goal of the experiment was to study the effect of three dietary densities (amino acids) in the pre-starter, starter, grower and finisher diets on body weight, feed conversion and feed intake of broiler chickens.

3.1.2 Experimental design

The experimental chickens were placed during May 2002 and housed at 16.0 birds per square metre. The three dietary treatments were assigned to the 24 pens (15 m^2 each) in a 3 x 6 randomised block design with 240 Ross 788 chickens per pen. The formulated dietary specifications of the treatments are outlined in Table 1 and Figure 12. The values given in Table 1, are the target values as formulated using Format (Format,. 2002). The following raw material nutrients were updated according to the latest laboratory results at the time of feed formulation: protein, moisture, calcium, phosphorus, sodium, ash, fat and fibre. Energy and amino acid concentrations were calculated according to a commercial feed mill's matrix values. (These can for obvious reasons not be disclosed in full). An amino acid profile, similar to that described by Baker and Han (1994) and Mack *et al.,* (1999), were used to adjust the whole essential amino acid profile to the digestible lysine concentration. The diets were fed according to the schedule in Table 3.

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Table 1 Formulated nutrient values of the three sets of diets (A, B and C) used in Trial One

Treat-ment	Feed	AMEn	Protein (%)	Fat (%)	Water (%)	Ash (%)	Carboh (%)	Dig Lys (%)*	Dig Lys (%) : ME (Mcal)
Grouped by type									
A	Pre-starter	13.00	24.70	4.70	11.50	6.00	53.10	1.33	0.43
B	Pre-starter	13.00	23.80	4.60	11.50	6.00	54.10	1.28	0.41
C	Pre-starter	13.00	22.85	4.50	11.50	6.00	55.15	1.24	0.40
A	Starter	13.00	22.90	4.50	11.50	6.00	55.10	1.24	0.40
B	Starter	13.00	21.93	4.40	11.50	6.00	56.17	1.18	0.38
C	Starter	13.00	21.02	4.32	11.50	6.00	57.16	1.13	0.36
A	Grower	13.13	20.60	5.00	11.50	6.00	56.90	1.09	0.35
B	Grower	13.13	20.00	4.95	11.50	6.00	57.55	1.05	0.33
C	Grower	13.13	20.00	5.00	11.50	6.00	57.50	0.99	0.32
A	Finisher	13.30	18.80	5.00	11.50	5.30	59.40	1.00	0.31
B	Finisher	13.30	17.70	5.00	11.50	5.30	60.50	0.94	0.30
C	Finisher	13.30	17.00	5.00	11.50	5.30	61.20	0.89	0.28
Grouped by treatment:									
A	Pre-starter	13.00	24.70	4.70	11.50	6.00	53.10	1.33	0.43
A	Starter	13.00	22.90	4.50	11.50	6.00	55.10	1.24	0.40
A	Grower	13.13	20.60	5.00	11.50	6.00	56.90	1.09	0.35
A	Finisher	13.30	18.80	5.00	11.50	5.30	59.40	1.00	0.31
B	Pre-starter	13.00	23.80	4.60	11.50	6.00	54.10	1.28	0.41
B	Starter	13.00	21.93	4.40	11.50	6.00	56.17	1.18	0.38
B	Grower	13.13	20.00	4.95	11.50	6.00	57.55	1.05	0.33
B	Finisher	13.30	17.70	5.00	11.50	5.30	60.50	0.94	0.30
C	Pre-starter	13.00	22.85	4.50	11.50	6.00	55.15	1.24	0.40
C	Starter	13.00	21.02	4.32	11.50	6.00	57.16	1.13	0.36
C	Grower	13.13	20.00	5.00	11.50	6.00	57.50	0.99	0.32
C	Finisher	13.30	17.00	5.00	11.50	5.30	61.20	0.89	0.28

* Digestible Lys is calculated as 95% of the total dietary Lys

3.1.3 Bird management

Standard commercial broiler management procedures were followed, starting with a 24-hour day length at day one and a 23-hour day length thereafter. Brooding temperature started at ±32°C and was reduced by 2.5°C per week until ±22°C was reached. The vaccination and feeding programmes are outlined in Tables 2 and 3 respectively.

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Table 2 Vaccination programme and method of application used in Trials One and Two

Age	Vaccine	Method
1 day	NCD Avinew / IB H120	Spray
18 days	BUR 706	Water
21 days	NCD Avinew	Water

Table 3 Feeding programme (g/bird and age) and physical form of the feed used in Trial One

Diets	Feed weight (Kg/bird)	Age (days)	Feed form
Pre-starter	0.200	0-7	Crumbles
Starter	0.900	8-18	Crumbles
Grower	1.400	19-30	Pellets
Finisher	±0.500	31-35	Pellets
Total	±3.000		

3.1.4 Observations

Live body weight was recorded on 1, 14, 21, 28, and 35 days of age by weighing all birds. The average weight of broilers on day one was 40 g per bird. Mortalities are outlined in Table 4. Feed intake was recorded on a weekly basis, while mortalities were recorded daily. No adjustments for mortality were made in the calculation of FCR, i.e. total feed consumption per replicate was divided by total live weight of birds in the pen at 35 days of age.

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Table 4 Mortality (%) at 7, 14, 28 and 35 days of age for Trial One

Treatments	Mortality (%)			
	7 Days	14 Days	28 Days	35 Days
A	0.83_a	2.50_a	4.10_a	5.00_a
B	0.63_a	1.74_a	2.50_a	3.33_a
C	0.90_a	1.81_a	2.92_a	4.03_a

[a] Column means with common subscripts do not differ (P>0.05)

3.1.5 Statistical analyses

Statistical analyses were done by using Statgraphics (1991).

3.1.6 Results

The production results to 35 days of age are presented in Table 6. Body weight decreased steadily as dietary density decreased from treatment A to C. Body weight did not differ ($P<0.05$) between treatments. Feed intake increased from A to C to compensate for the lower amino acid density. Scientific literature (Leeson 1996a, Emmert *et al.,* 2000 Noy & Sklan 2002 and Sklan & Plavnik, 2002) and the EFG broiler model (see Table 7) confirm that feed intake should increase as amino acid density decreases. The FCR increased over the range of diets, although the difference was not significant ($P<0.05$). Mortality did not differ significantly between treatments, although A showed the highest ascites mortalities. (see Table 5)

The production efficiency factor (PEF) was calculated as follows:

$$\frac{\text{(percentage liveability x body weight in kg) x 100}}{\text{(feed conversion ratio x age in days)}}$$

The PEF did not differ significantly, but decreased with dietary density.

Margin over feed cost was calculated as follows:

(Live weight [in kg @ 35 days of age] x R6.50 per kg) – (Feed cost [weighted according to feeding programme; R/kg] x feed intake [kg]).

Yield was calculated as: (average kg live weight x (240 birds per pen– total number mortalities)/15m^2)

In spite of the higher weight and better FCR and PEF of A, the margin over feed cost for A (R4.86) was lower than for treatment B (R4.93) and C (R4.96). This observation confirms that maximizing PEF does not necessary maximise profit. (see Table 6)

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Table 5 Observed ascites mortalities as percentage of total birds and percentage of total mortalities (1 to 35 days) for Trial One

Treatments	Ascites mortality	
	Percentage of total birds	Percentage of total mortality
A	1.45_b	28.96_a
B	0.49_a	18.28_a
C	0.77_a	18.27_a

[a,b] Column means with common subscripts do not differ (P>0.05)

Table 6 The broiler production results at 35 days of age of three dietary treatments decreasing in amino acid density with A (high) to C (low) throughout the range of pre-starter to finisher diets: Trial One

Treatment	A	B	C
Body weight (kg)	1.958_a	1.952_a	1.945_a
Feed intake (kg/bird)	3.006_a	3.023_a	3.041_a
Feed conversion (kg/kg)	1.535_a	1.549_a	1.563_a
Mortality (%)	5.00_a	3.33_a	4.03_a
Live weight yield (kg/m^2)	29.8	30.2	29.9
PEF	346.2	348.1	341.2
Margin over feed cost (R/bird)	4.86	4.93	4.96

[a] Row means with common subscripts do not differ (P>0.05)

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3.2 SIMULATION OF TRIAL ONE ON THE EFG BROILER MODEL

3.2.1 Discussion:

The diets shown in Table 1 were used in the EFG model to predict broiler response. Simulated performance results were compared to the actual results from 7 to35 days of age. Details of parameters used in the model are shown in Appendix 1. Table 7 summarizes the predicted vs. actual results for Trial One.

3.2.1.1 Live weight

Predicted 7 day weights for the three treatments were on average 10 g higher than actual weights, i.e. 163.3 g EFG-predicted vs. 153.3 g actual weights. Although seven-day weights are normally ±10 g higher in the test facility being used than in commercial broiler houses, actual weights could not reach the predicted weights at seven days. It is, however, known that South African seven-day weights are normally higher at sea level than at altitude where these trials were performed. Most of the model's data originated from trials performed at sea level.

Actual body weights from 14 to 35 days of age were higher than predicted values. The average difference between predicted and actual weights was relatively constant for 21 days (+69 g), 28 days (+88 g) and 35 days (+77 g). As seen in Table 7, the differences in actual and predicted weight were 86 g, 72 g and 72 g for treatment A to C at 35 days respectively. The difference for treatment A was slightly higher than for B and C.

Dietary density decreased from treatment A to C. Growth rate was therefore expected to decrease and feed intake to increase from treatment A to C. Actual weights followed the expected trend from 21 to 35 days of age although the differences were not significant ($P<0.05$). Predicted values, however, followed this pattern only to 21 days. From 28 to 35 days, a slight increase was calculated for treatment B before decrease to C. The maximum difference between predicted values at 35 days was 8 g (i.e. B less A) and 13 g for actual weights (i.e. A less C). Figure 7 shows how the predicted weights increased slightly for treatment B while the actual weights decreased steadily for treatment A to C at 35 days.

3.2.1.2 Feed intake and feed conversion

The average actual intake was higher than predicted values from 7 to 35 days of age. (see Table 7) This difference increased from 14 and 37 g at 7 and 14 days to a steady 105, 117 and 110 g at 21, 28 and 35 days. The higher actual intake resulted in the higher actual weights as compared to predicted values. The difference between actual and predicted values were higher for treatment A, than for treatment B and C. This partly explains the bigger difference between actual and predicted weight in treatment A.

Predicted intake values increased as expected from treatment A to C from 14 to 35 days of age. Actual intakes, however, followed a different trend with a decrease in intake at 21 and 28 days for treatment B. At 35 days of age both predicted and actual intakes showed an increase from treatment A to C (Figure 9, Table 7).

The average difference between actual and predicted feed conversion was basically 0.08 from 14 to 35 days. With the exception of the actual 28 day FCR value, predicted and actual FCR values increased as dietary density decrease from A to C. Figure 8 shows how both actual and predicted 35-day FCR increases from treatment A to C.

3.2.1.3 PEF

Actual and predicted PEF followed a general decreased trend. (see Figure 10) The slightly higher

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actual PEF for B was due to a difference in mortality of 5% and 3.3% for A and B respectively. When all actual treatments were calculated on 5% mortality, as with predicted values, the PEF values were 346, 342 and 338 for treatment A to C respectively. The new difference between actual and predicted values will then be 2, 1 and 4 points respectively. (see Table 7)

3.2.1.4 Margin over feed cost

Both actual and predicted values indicated an increased margin over feed cost for B and C. Although the absolute values differ, differences were constant at 22, 21 and 25 sent per bird. It is clear from Table 7 and Figure 11 that optimum profit will be realised by using the lower density diets B and C.

3.2.1.5 Correlation coefficients

Correlation coefficients were calculated for live weight feed intake, FCR (day 7 to 35), PEF and margin over feed cost at 35 days (Table 7). Good correlation coefficients were calculated for FCR (R=1.0 for days 14,21, and 35), but those for intake and weight varied between ages. (see Table 7) Reasonable correlations were calculated for PEF (R=0.81 at 35 days, actual mortality), PEF (R=0.98 at 35 days, calculated at 5% mortality) and margin over feed cost (R=0.92 at 35 days).

3.2.2 Conclusion

The decrease in amino acid concentration of 5% from treatments A to C (i.e. from prestarter to finisher), resulted in the following: Body weights did not differ significantly. Predicted weights increased slightly with a maximum difference of 8 g between treatments while actual weights decreased with a maximum of 13 g from the highest to the lowest value. Poor correlation coefficients were calculated between actual and predicted weights from 7 to 35 days.

Actual intake to 35 days increased steadily with a 35 g difference between A and C. Predicted intake to 35 days increased steadily with an 85 g difference between A and C. The birds can, therefore, compensate for lower density diets by increasing feed intake. Actual intake was on average 110 g higher than predicted intakes, which explains to a large extent the average of 77 g higher actual body weights at 35 days. The ratio 110/77 results in 1.43, which is very close to the actual average FCR of 1.54. Although values differed, a high correlation coefficient of 0.99 was calculated between actual and predicted intake at 35 days.

Actual FCR was constantly higher (+0.08) than the predicted FCR. Actual FCR at 35 days increased steadily with a 2.8-point difference between A and C. Predicted FCR at 35 days increased steadily with a 5-point difference between A and C. A correlation coefficient of 0.99 was calculated between actual and predicted FCR at 35 days.

In spite of differences in weight and intake between actual and predicted values, the PEF values, calculated on 5% mortality for all treatments, differed with only 1 to 4 points. This indicates on overall good comparison between predicted and actual trial values.

Predicted PEF values decreased with 10 points from A to C while actual PEF values, calculated on 5% mortality, decreased by 8 points from A to C. Predicted margin over feed cost increased with 8 cents from A to B while actual margin over feed cost increased by 7 cents from A to B. These values indicate how sensitive the results can be to a change of 5% in amino acid concentration. It also stresses the fact that the higher density diets do not always maximize profit.

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Table 7 Comparison between EFG-predicted and actual performance data at 7, 14, 21, 28 and 35 days of age for Trial One: amino acid concentration decreases throughout the range of prestarter to finisher diets, A=high and C=Low.

Age (d): 7	Act vs. Pred. Wt (g)			Age (d): 14				Age (d): 21				Age (d): 28				Age (d): 35				Age (d): 35	Act vs. Pred PEF	Actual mortality used	
Feed	Pred. Wt. (g)	Act. Wt. (g)	Diff. Act vs. Pred.	Feed	Pred. Wt. (g)	Act. Wt. (g)	Diff. Act vs. Pred.	Feed	Pred. Wt. (g)	Act. Wt. (g)	Diff. Act vs. Pred.	Feed	Pred. Wt. (g)	Act. Wt. (g)	Diff. Act vs. Pred.	Feed	Pred. Wt. (g)	Act. Wt. (g)	Diff. Act vs. Pred.		Pred PEF	Actual PEF	Diff. Act vs. Pred.
A	167.0	153.8	-13.2	A	406.0	425.7	19.7	A	784.0	856.7	72.7	A	1300.0	1393.6	93.6	A	1872.0	1958.0	86.0	A	344	346	2
B	164.0	151.5	-12.5	B	404.0	418.7	14.7	B	779.0	842.0	63.0	B	1302.0	1386.8	84.8	B	1880.0	1952.0	72.0	B	341	348	8
C	159.0	154.3	-4.7	C	395.0	421.8	26.8	C	771.0	840.3	69.3	C	1290.0	1376.8	86.8	C	1873.0	1945.0	72.0	C	334	341	7
Avg.	163.3	153.2	-10.1	Avg.	401.7	422.1	20.4	Avg.	778.0	846.3	68.3	Avg.	1297.3	1385.7	88.4	Avg.	1875.0	1951.7	76.7	Avg.	339.5	345.0	5.5
Cor.		-0.30		Cor.		0.23		Cor.		0.85		Cor.		0.84		Cor.		-0.07		Cor.		0.82	
Age (d): 7	Act. vs. Pred. Intake (g)			Age (d): 14				Age (d): 21				Age (d): 28				Age (d): 35				Age (d): 35	Act vs. Pred PEF	5% mortality used	
	Pred Intake (g)	Actual intake (g)	Diff. Act vs. Pred.		Pred Intake (g)	Actual intake (g)	Diff. Act vs. Pred.		Pred Intake (g)	Actual intake (g)	Diff. Act vs. Pred.		Pred Intake (g)	Actual intake (g)	Diff. Act vs. Pred.		Pred Intake (g)	Actual intake (g)	Diff. Act vs. Pred.		Pred PEF	Actual PEF	Diff. Act vs. Pred.
A	120.0	132.0	12.0	A	411.9	452.3	40.4	A	943.6	1059.6	116.0	A	1797.5	1939.3	141.8	A	2868.4	3006.0	137.6	A	344	346	2
B	121.0	132.3	11.3	B	421.8	452.2	30.4	B	956.0	1054.0	98.0	B	1820.3	1924.3	104.0	B	2919.7	3023.0	103.3	B	341	342	1
C	118.0	135.3	17.3	C	423.6	464.3	40.7	C	971.7	1074.4	102.7	C	1835.9	1942.0	106.1	C	2953.2	3041.0	87.8	C	334	338	4
Avg.	119.67	133.22	13.55	Avg.	419.10	456.24	37.14	Avg.	957.10	1062.67	105.57	Avg.	1817.90	1935.21	117.31	Avg.	2913.77	3023.33	109.57	Avg.	339	342	3
Cor.		-0.92		Cor.		0.62		Cor.		0.75		Cor.		0.03		Cor.		0.99		Cor.		0.98	
Age (d): 7	Actual vs. Pred. FCR			Age (d): 14				Age (d): 21				Age (d): 28				Age (d): 35					Act. vs. Pred Margin Feed cost		
	Pred FCR (kg/kg)	Actual FCR (kg/kg)	Diff. Act vs. Pred.		Pred FCR (kg/kg)	Actual FCR (kg/kg)	Diff. Act vs. Pred.		Pred FCR (kg/kg)	Actual FCR (kg/kg)	Diff. Act vs. Pred.		Pred FCR (kg/kg)	Actual FCR (kg/kg)	Diff. Act vs. Pred.		Pred FCR (kg/kg)	Actual FCR (kg/kg)	Diff. Act vs. Pred.		Pred	Actual	Diff. Act vs. Pred.
A	0.838	0.858	0.020	A	1.136	1.062	-0.074	A	1.310	1.237	-0.073	A	1.476	1.392	-0.084	A	1.610	1.535	-0.075	A	R 4.64	R 4.86	R 0.22
B	0.860	0.873	0.013	B	1.172	1.080	-0.092	B	1.334	1.252	-0.082	B	1.494	1.388	-0.106	B	1.630	1.549	-0.081	B	R 4.72	R 4.93	R 0.21
C	0.873	0.877	0.004	C	1.207	1.101	-0.106	C	1.373	1.279	-0.094	C	1.521	1.411	-0.110	C	1.660	1.563	-0.097	C	R 4.71	R 4.96	R 0.25
Avg.	0.85	0.87	0.02	Avg.	1.15	1.07	-0.08	Avg.	1.32	1.24	-0.08	Avg.	1.49	1.39	-0.10	Avg.	1.62	1.54	-0.08	Avg.	4.69	4.92	0.23
Cor.		0.98		Cor.		1.00		Cor.		1.00		Cor.		0.84		Cor.		1.00		Cor.		0.92	

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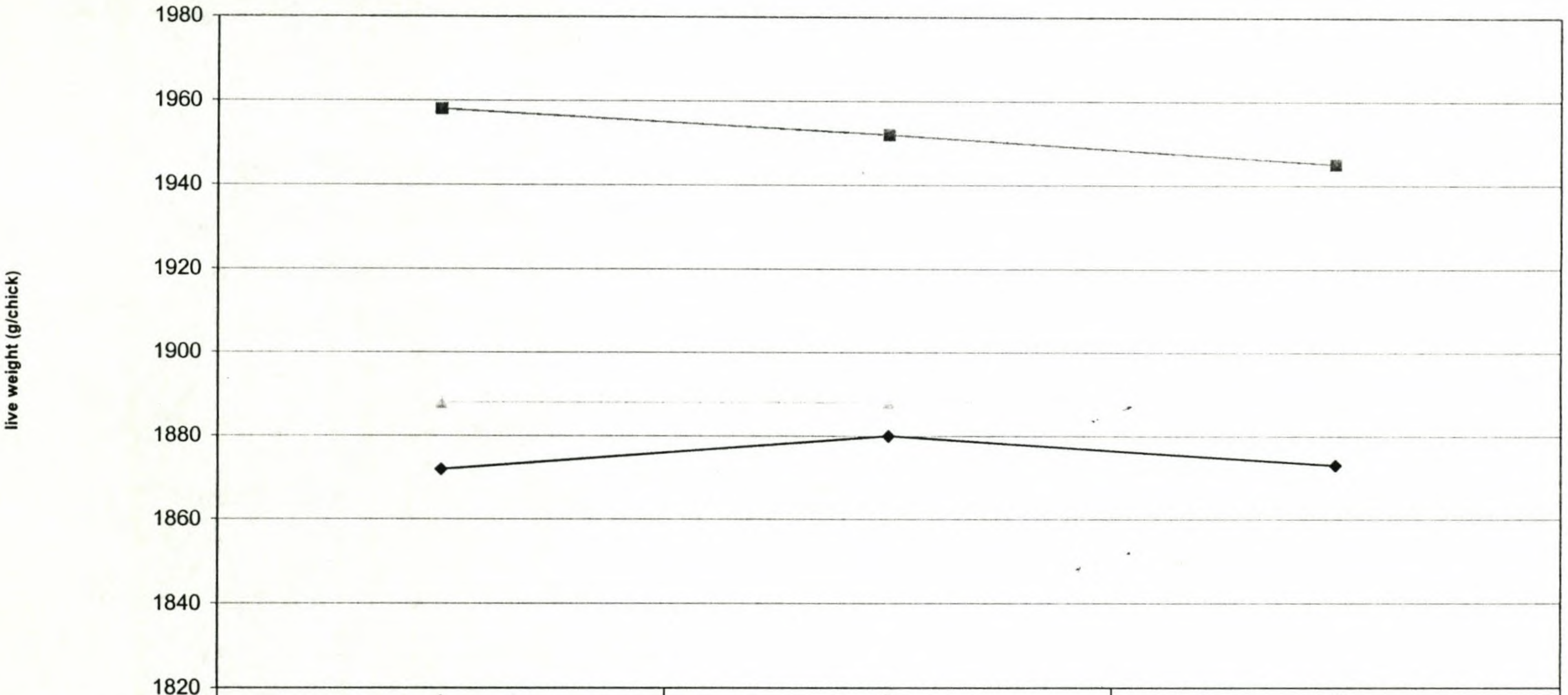
Actual vs. predicted weight at 35 days



	A	B	C
Pred Weight (g)	1872	1880	1873
Act weight (g)	1958	1952	1945
Potential weight	1888	1888	1888

Treatment

Figure 7 Actual, EFG-predicted and EFG-potential live weight (g) at 35 days of age for Trial One: amino acid concentration decreases throughout the range of prestarter to finisher diets, A=high and C=Low.

Potential growth data (weight, feed intake or FCR): Details of the potential growth of the broiler are calculated at the same time as the actual growth is simulated. For this calculation it is assumed that there are no limitations to growth except those imposed by the genotype and adjustments to the growth constraint and husbandry factors (EFG Broiler Growth Model, 1999)

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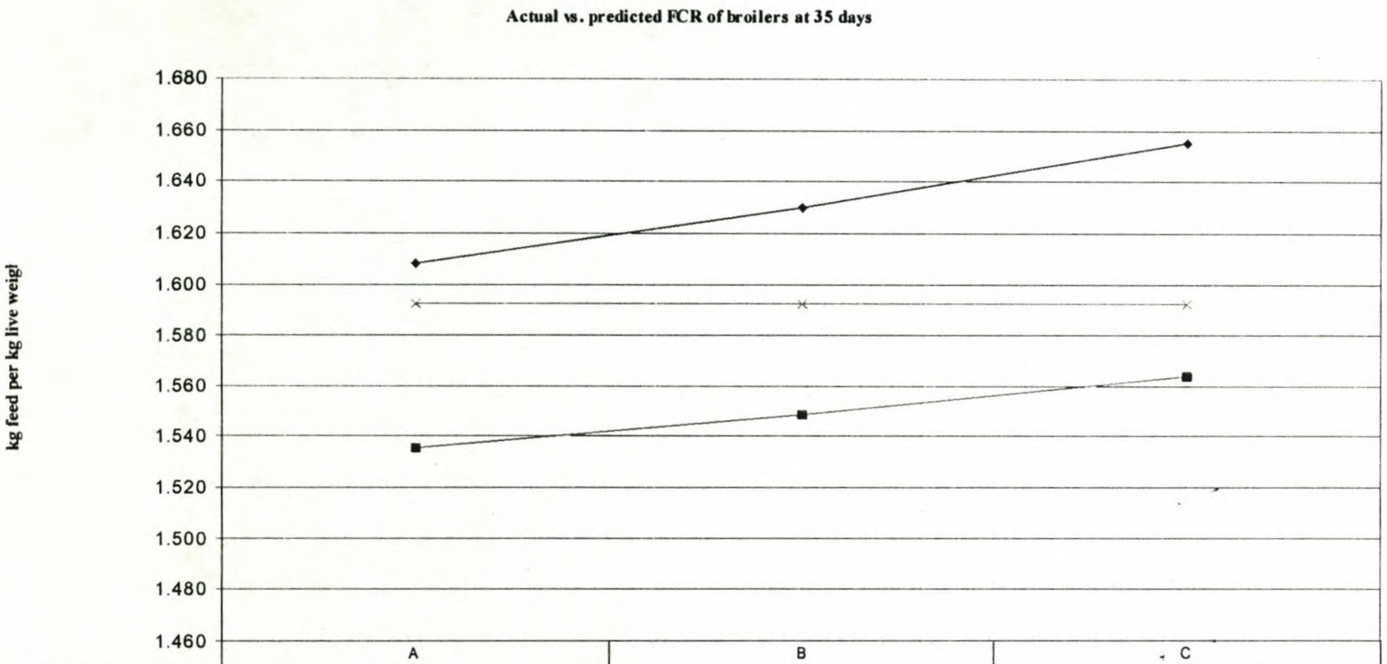

	A	B	C
Pred FCR (kg/kg)	1.608	1.630	1.655
Actual FCR (kg/kg)	1.535	1.549	1.563
Potential FCR	1.592	1.592	1.592

Treatment

Figure 8 Actual, EFG-predicted and EFG-potential FCR (kg feed / kg live weight) at 35 days of age for Trial One: amino acid concentration decreases throughout th range of prestarter to finisher diets, A=high and C=Low.

Potential growth data (weight, feed intake or FCR): Details of the potential growth of the broiler are calculated at the same time as the actual growth is simulated. For this calculation it is assumed that there are n limitations to growth except those imposed by the genotype and adjustments to the growth constraint and husbandry factors (EFG Broiler Growth Model, 1999)

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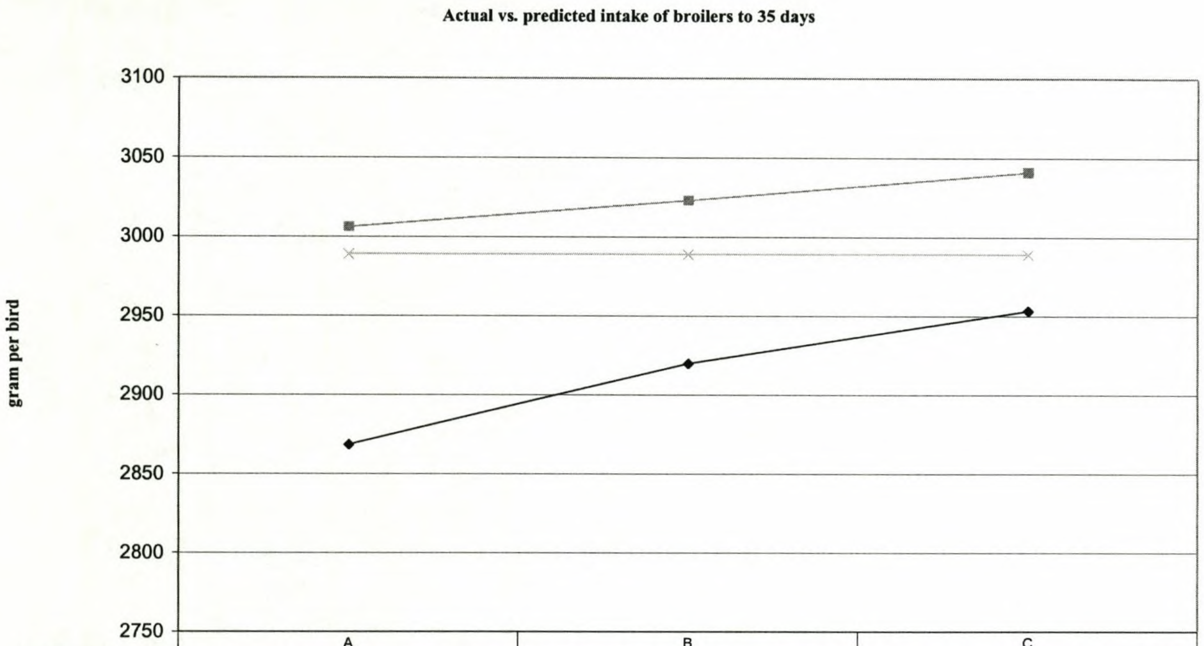

	A	B	C
Pred Intake (g)	2868	2920	2953
Actual intake (g)	3006	3023	3041
Potential Intake	2989	2989	2989

Treatment

Figure 9 Actual, EFG-predicted and EFG potential feed intake (g/bird) at 35 days of age for Trial One: amino acid concentration decreases throughout the range of prestarter to finisher diets, A=high and C=Low.

Potential growth data (weight, feed intake or FCR): Details of the potential growth of the broiler are calculated at the same time as the actual growth is simulated. For this calculation it is assumed that there are no limitations to growth except those imposed by the genotype and adjustments to the growth constraint and husbandry factors (EFG Broiler Growth Model, 1999)

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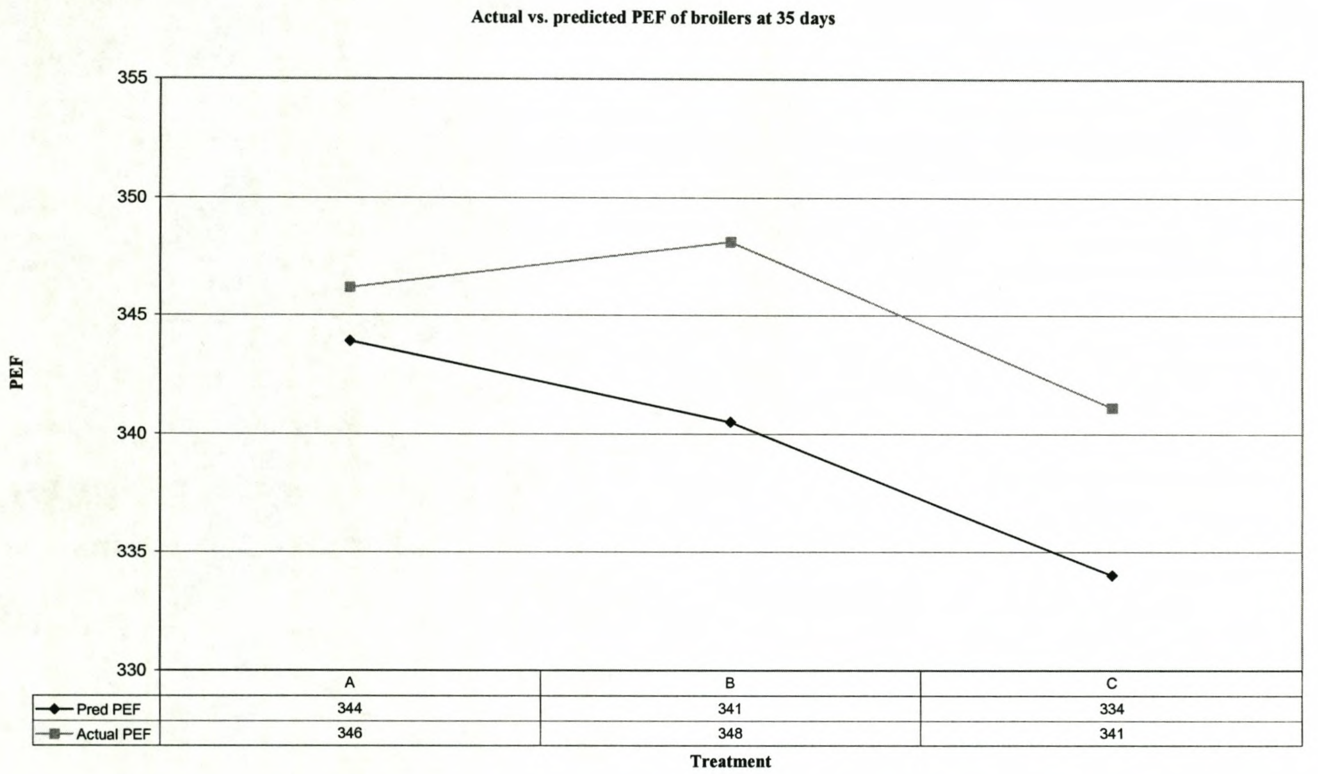

Figure 10 Actual vs. EFG-predicted PEF at 35 days of age for Trial One: amino acid concentration decreases throughout the range of prestarter to finisher diets, A=high and C=Low.

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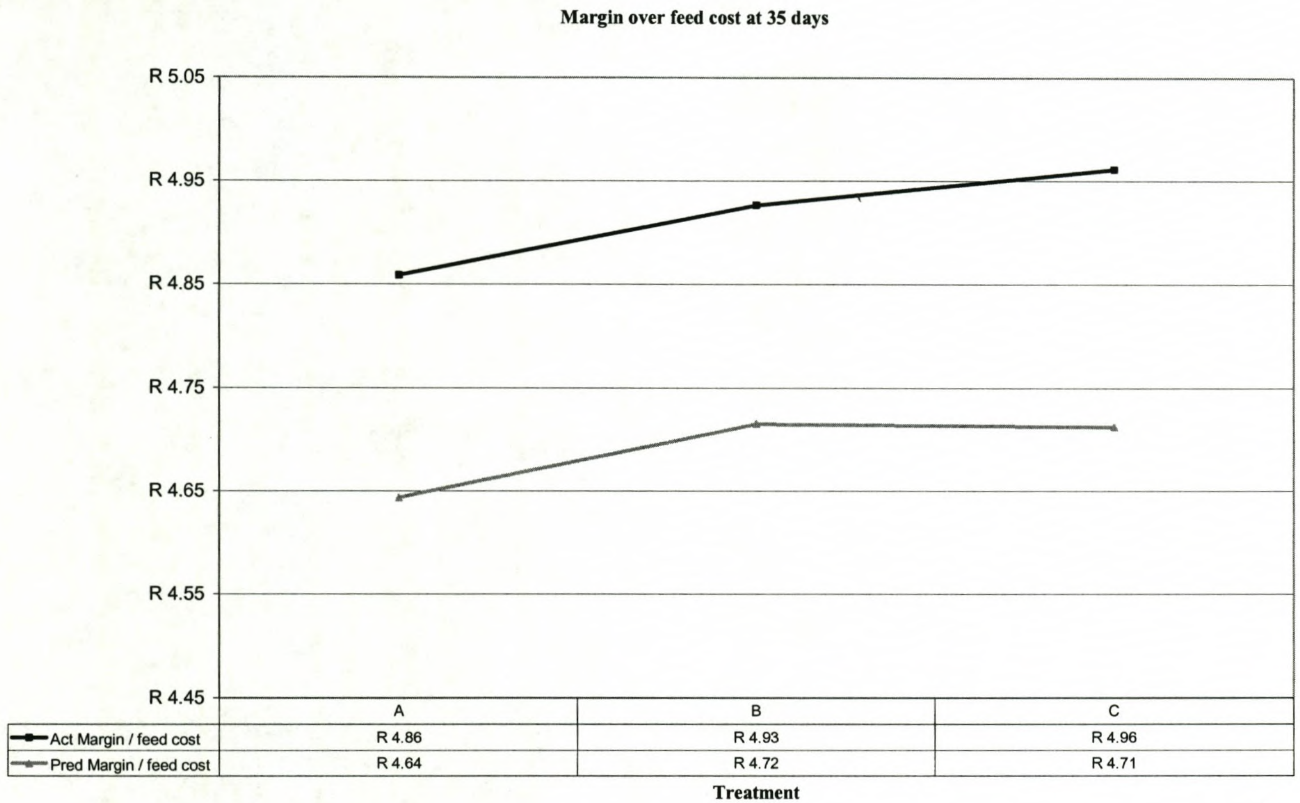

	A	B	C
Act Margin / feed cost	R 4.86	R 4.93	R 4.96
Pred Margin / feed cost	R 4.64	R 4.72	R 4.71

Figure 11 Actual vs. EFG-predicted margin over feed cost (R/bird) for Trial One: amino acid concentration decreases throughout the range of prestarter to finisher diets, A=high and C=Low.

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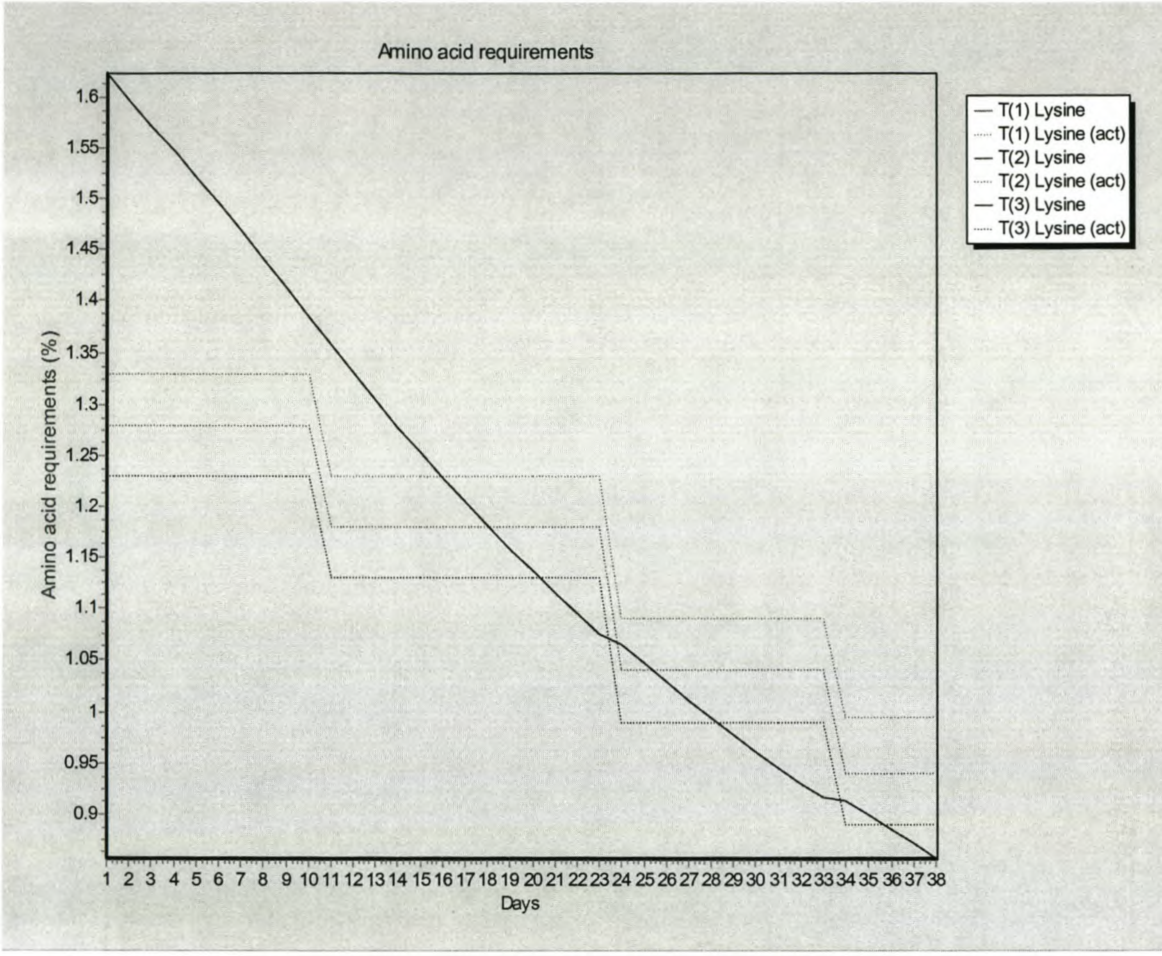

Figure 12 Digestible amino acid levels (%) for the three dietary treatments from day 1 to 38.

The top stepped line represents the amino acid levels of treatment A, from pre-starter to finisher, and is indicated as T(1) in the graph. The middle stepped line represents the amino acid levels of treatment B, from pre-starter to finisher, and is indicated as T(2) in the graph.

The bottom stepped line represents the amino acid levels of treatment C, from pre-starter to finisher, and is indicated as T(3) in the graph.

The solid diagonal line represents the amino acid requirement from day 1 to 38.

Although the programme is indicated to 38 days, all calculations were made with data for day 35

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4. BROILER TRIAL TWO

4.1 THE INFLUENCE OF FOUR AMINO ACID DENSITIES IN THE FINISHER PHASE ON BROILER PERFORMNANCE

4.1.1 Goal

The goal of the experiment was to study the effect of four dietary densities (amino acids) in the finisher stage (day 30 to 35) on body weight, feed conversion and feed intake of broiler chickens

4.1.2 Experimental design

The experimental chickens were placed during August 2002 and housed at 16.0 birds per square metre. The four dietary treatments were assigned to the 24 pens (15m^2 each) in a 4 x 6 randomised block design with 240 Ross 788 chickens per pen. The formulated dietary specifications of the treatments are outlined in Table 8 and Figure 18. The values given in Table 8 are the target values as formulated using Format (Format,. 2002). The following raw material nutrients were updated according to the latest laboratory results at the time of feed formulation: protein, moisture, calcium, phosphorus, sodium, ash, fat and fibre. Energy and amino acid concentrations were calculated according to a commercial feed mill's matrix values. (These can for obvious reasons not be disclosed in full). An amino acid profile, similar to that described by Baker and Han (1994) and Mack *et al.,* (1999), were used to adjust the whole essential amino acid profile to the digestible lysine concentration. The diets were fed according to the schedule in Table 9.

4.1.3 Bird management

Standard commercial broiler management procedures were followed, starting with a 24-hour day length at day one and a 23-hour day length thereafter. Brooding temperature started at ±32°C and was reduced by 2.5°C per week until ±22°C was reached. The vaccination and feeding programmes are outlined in Tables 2 and 9 respectively.

4.1.4 Observations

Live body weight was recorded at 1, 14, 21, 28, and 35 days of age by weighing all birds. The average weight of broilers on day one was 43 g per bird. Mortalities are outlined in Table 10. Feed intake was recorded on a weekly basis, while mortalities were recorded daily. No adjustments for mortality were made in the calculation of FCR, i.e. total feed consumption per replicate was divided by total live weight of birds in the pen at 35 days of age.

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Table 8 Formulated nutrient values of the four sets of diets (A, B, C and D) used in Trial Two
(Similar specifications were used for the pre-starter, starter and grower diets)

Treat-ment.	Feed	AMEn	Protein (%)	Fat (%)	Water (%)	Ash (%)	Carboh (%)	Dig Lys (%)*	Dig Lys (%) : ME (Mcal)
Grouped by type									
A	Pre-starter	13.00	24.70	4.50	11.50	6.00	53.30	1.33	0.43
B	Pre-starter	13.00	24.70	4.50	11.50	6.00	53.30	1.33	0.43
C	Pre-starter	13.00	24.70	4.50	11.50	6.00	53.30	1.33	0.43
D	Pre-starter	13.00	24.70	4.50	11.50	6.00	53.30	1.33	0.43
A	Starter	13.00	22.90	4.30	11.50	6.00	55.30	1.24	0.40
B	Starter	13.00	22.90	4.30	11.50	6.00	55.30	1.24	0.40
C	Starter	13.00	22.90	4.30	11.50	6.00	55.30	1.24	0.40
D	Starter	13.00	22.90	4.30	11.50	6.00	55.30	1.24	0.40
A	Grower	13.08	20.20	4.60	11.50	6.00	57.70	1.09	0.35
B	Grower	13.08	20.20	4.60	11.50	6.00	57.70	1.09	0.35
C	Grower	13.08	20.20	4.60	11.50	6.00	57.70	1.09	0.35
D	Grower	13.08	20.20	4.60	11.50	6.00	57.70	1.09	0.35
A	Finisher	13.30	19.00	4.70	11.50	5.30	59.50	1.05	0.33
B	Finisher	13.30	17.87	4.50	11.50	5.30	60.83	0.97	0.31
C	Finisher	13.30	17.00	4.10	11.50	5.30	62.10	0.89	0.28
D	Finisher	13.30	17.00	4.00	11.50	5.30	62.20	0.86	0.27
Grouped by treatment									
A	Pre-starter	13.00	24.70	4.50	11.50	6.00	53.30	1.33	0.43
A	Starter	13.00	22.90	4.30	11.50	6.00	55.30	1.24	0.40
A	Grower	13.08	20.20	4.60	11.50	6.00	57.70	1.09	0.35
A	Finisher	13.30	19.00	4.70	11.50	5.30	59.50	1.05	0.33
B	Pre-starter	13.00	24.70	4.50	11.50	6.00	53.30	1.33	0.43
B	Starter	13.00	22.90	4.30	11.50	6.00	55.30	1.24	0.40
B	Grower	13.08	20.20	4.60	11.50	6.00	57.70	1.09	0.35
B	Finisher	13.30	17.87	4.50	11.50	5.30	60.83	0.97	0.31
C	Pre-starter	13.00	24.70	4.50	11.50	6.00	53.30	1.33	0.43
C	Starter	13.00	22.90	4.30	11.50	6.00	55.30	1.24	0.40
C	Grower	13.08	20.20	4.60	11.50	6.00	57.70	1.09	0.35
C	Finisher	13.30	17.00	4.10	11.50	5.30	62.10	0.89	0.28
D	Pre-starter	13.00	24.70	4.50	11.50	6.00	53.30	1.33	0.43
D	Starter	13.00	22.90	4.30	11.50	6.00	55.30	1.24	0.40
D	Grower	13.08	20.20	4.60	11.50	6.00	57.70	1.09	0.35
D	Finisher	13.30	17.00	4.00	11.50	5.30	62.20	0.86	0.27

* Digestible Lys is calculated as 95% of the total dietary Lys

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Table 9 Feeding programme (g/bird and age) and physical form of the feed used in Trial Two

Diets	Feed weight (Kg/bird)	Age (days)	Feed form
Pre-starter	0.200	0-7	Crumbles
Starter	0.800	8-18	Crumbles
Grower	1.500	19-30	Pellets
Finisher	±0.530	31-35	Pellets
Total	±3.030		

Table 10 Observed mortality (%) at 7, 14, 28 and 35 days of age in Trial Two

Treatments	Mortality (%)			
	7 Days Same diet fed to A-D	14 Days Same diet fed to A-D	28 Days Same diet fed to A-D	35 Days Different diets fed to A,B,C and D
A	0.76_a	0.97_a	3.06_a	3.61_a
B	0.49_a	0.97_a	2.57_a	3.40_a
C	0.35_a	0.83_a	2.02_a	2.64_a
D	0.56_a	1.46_a	2.43_a	3.13_a

[a] Column means with common subscripts do not differ ($P>0.05$)

4.1.5 Statistical analyses

Statistical analyses were done by using Statgraphics (1991).

4.1.6 Results

The production results to 35 days of age are outlined in Table 12. Differences ($P<0.05$) in body weight were observed at 35 days as amino acid levels decreased with average 6% from A to D. The weight decreased with 26, 19 and 19 g from A to B, B to C and C to D respectively. Feed intake did not show any difference ($P\leq0.05$). Feed intake increased with 32 g from A to B, 8 g from B to C and decreased with 3 g from C to D. A difference ($P\leq0.05$) in feed conversion was obtained. Feed conversion increased with 3.7 points from A to B, 1.9 points from B to C and with 1.5 points from C to D. There was no difference ($P\leq0.05$) in mortality between treatments. Treatment A achieved the best yield, PEF, as well as margin over feed cost. Amino

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acid density during the finisher period (30 to 35 days) did not have any influence ($P \leq 0.05$) on ascites mortality. (see Table 11)

Table 11 Observed ascites mortalities as percentage of total birds and percentage of total mortalities (1 to 35 days) for Trial Two

Treatments	Ascites mortality	
	Percentage of birds	Percentage of total mortality
A	0.28_a	7.94_a
B	0.35_a	9.00_a
C	0.28_a	12.10_a
D	0.63_a	24.37_a

[a] Row means with common superscripts do not differ ($P>0.05$)

Table 12 The broiler production results at 35 days of age of four dietary treatments decreasing in amino acid density in the finisher diets only from A (high) to D (low): Trial Two

Trait	Broiler diets			
	A	B	C	D
Body weight (kg)	1.982_c	1.956_{bc}	1.937_{ab}	1.918_a
Feed intake (kg/bird)	3.030_a	3.062_a	3.070_a	3.067_a
Feed conversion (kg/kg)	1.529_a	1.566_b	1.585_{bc}	1.600_c
Mortality (%)	3.61_a	3.40_a	2.64_a	3.13_a
Live weight yield (kg/m^2)	30.6	30.2	30.2	29.7
PEF	356.9	344.7	339.9	331.8
Margin over feed cost (R/bird)	4.92	4.73	4.64	4.54

[a,b,c] Row means with common superscripts do not differ ($P>0.05$)

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4.2 SIMULATION OF TRIAL TWO ON THE EFG BROILER MODEL

4.2.1 Discussion:

The diets shown in Table 8 were used in the EFG broiler model to predict broiler response. Simulated results were compared to the actual results at 35 days of age. Details of parameters used in the model are shown in Appendix 2. Table 13 summarises the actual vs. predicted values for the second simulation.

4.2.1.1 Live weight

The average predicted live weight for treatments A to D was 1872 g at 35 days and differed with only 3 g from the highest to lowest value. The average actual live weight for treatments A to D was 1948 g at 35 days and differed with 64 g from the highest to lowest value. The actual weight decreased by ±20 g between treatments as the amino acid density of the finisher diets decreased from treatment A to D.

The average actual weight at 35 days was 77 g higher than the average predicted weight. It is interesting to note that the difference between actual and predicted weights is the highest for treatment A (112 g) and the lowest for treatment D (47 g). (see Table 13)

4.2.1.2 Feed intake and feed conversion

The model predicted a small, steady increase in feed intake (+11, +8 and +6 g for A to B, B to C and C to D respectively) and a flat response on body weight (maximum 3 g from the highest to lowest value) resulting in similar values for FCR for A to D (i.e. 1.61 lowest and 1.62 highest).

The actual feed intake increased with 32 g from A to B, but the values for B to C and C to D did not show a clear trend (B-C: +8 g; C-D: -3 g at 35 days). The birds do, therefore, seem to compensate to some extent for the lower dietary density. In contrast with predicted values, actual weight decreased by ± 60 g from A to D. This resulted in a much steeper actual increase in FCR compared to predicted values. (see Figure 13 to 15)

Fitting a straight line to the predicted intake ($y = 8.26x + 2862.3$) resulted in a good fit ($R^2 = 0.98$). A straight line, however, did not fit the actual values very well: ($R^2 = 0.69$; $y = 11.9x + 3027$). However, the constants indicate a 165 g higher actual vs. predicted intake. This value is close to the actual average difference of 174 g. The higher intake partly explains the 77 g average higher actual body weight gain. (see Figures 13 and 15)

4.2.1.3 PEF, margin over feed cost and correlation coefficients

Actual PEF decreased with 12, 5 and 8 points for A to B, B to C and C to D respectively. The differences for predicted PEF were maximum 3 points between the lower and higher values. This was due to the slight increase in predicted feed intake without any real response in predicted body weight to 35 days. Figure 16 shows that actual PEF was 14 points higher for treatment A but decreased in relation to predicted values to 9 points lower than predicted values for treatment D. Table 13 shows how the difference between actual and predicted weights decrease from 112 to 47 g from A to D. The relative high actual body weight gave the actual PEF an advantage in treatment A.

The margin over feed cost decreased for actual data from A (R4.92 / bird) to D (R4.54 / bird). The best margin therefore correlated with the best PEF value. Due to the small differences in predicted values, the predicted margin over feed cost differed with only 2 cents, predicting the best profit for treatment B and C.

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4.2.2 Conclusion

The main difference between predicted and actual results was the response to body weight. The model predicted a steady increase in feed intake to compensate for the lower dietary specifications while body weight did not change significantly. The predicted increase in feed intake was enough to maintain body weight.

Actual trial date did show an increase in feed intake but no clear response could be identified between treatments B to D. The compensation was too low to maintain body weight compared to the control diet. The trial birds sacrificed ±20 g in body weight between treatments.

There is evidence in the literature that birds need 7 days to adapt to lower feed specification (Leeson *et al.*, 1996a). It can be speculated that these birds needed a few days to adapt to the lower finisher specification. They could have lost body weight due to a lower amino acid intake in this period. The model, however, seems to adapt feed intake immediately after a change in diet specification.

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Table 13 Comparison between EFG-predicted and actual performance data at 35 days of age for Trial Two: four dietary treatments decreasing in amino acid density in the finisher diets only from A (high) to D (low)

Age (d): 35	**Actual vs. Predicted Weight**		
Feed	Pred Weight (g)	Act weight (g)	Difference Act vs. Pred.
A	1870	1982	112
B	1873	1956	83
C	1872	1937	65
D	1871	1918	47
	Actual vs. Predicted FCR		
	Pred FCR (kg/kg)	Actual FCR (kg/kg)	Difference Act vs. Pred.
A	1.61	1.53	-0.08
B	1.61	1.57	-0.05
C	1.62	1.59	-0.03
D	1.62	1.60	-0.02
	Actual vs. Predicted Intake		
	Pred Intake (g)	Actual intake (g)	Difference Act vs. Pred.
A	2869	3030	161
B	2880	3062	182
C	2888	3070	182
D	2894	3067	173
	Actual vs. Predicted PEF		
	Pred PEF	Actual PEF	Difference Act vs. Pred.
A	343	357	+14
B	343	345	+2
C	342	340	-2
D	340	332	-8
	Actual vs. Predicted Margin/feed cost		
	Pred MOFC	Actual MOFC	Difference Act vs. Pred.
A	R 4.61	R 4.92	R 0.31
B	R 4.63	R 4.73	R 0.11
C	R 4.63	R 4.64	R 0.01
D	R 4.62	R 4.54	-R 0.08

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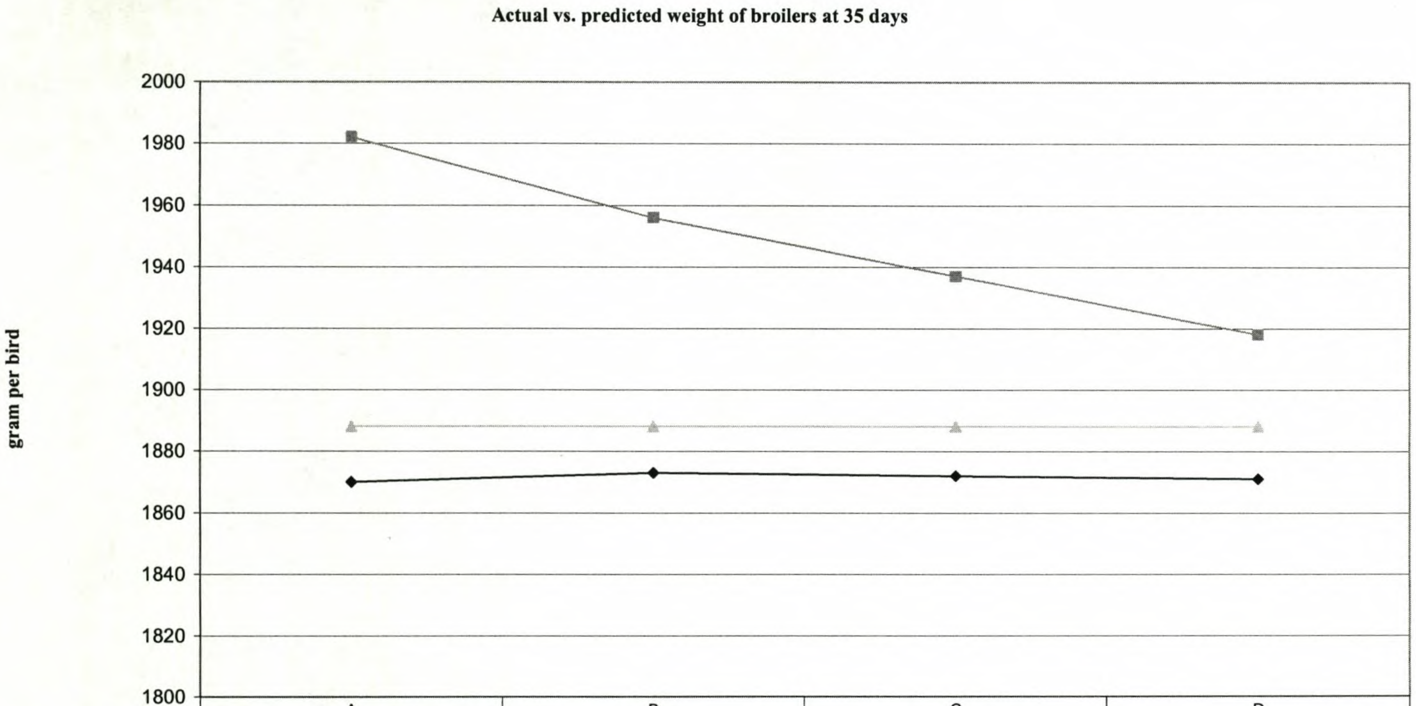

	A	B	C	D
Pred Weight (g)	1870	1873	1872	1871
Act weight (g)	1982	1956	1937	1918
Potential weight	1888	1888	1888	1888

Treatment

Figure 13 Actual, EFG-predicted and EFG-potential live weight (g) at 35 days of age for Trial Two: amino acid concentration decreases in the finisher diets only, A=high and C=Low.
Potential growth data (weight, feed intake or FCR): Details of the potential growth of the broiler are calculated at the same time as the actual growth is simulated. For this calculation it is assumed that there are no limitations to growth except those imposed by the genotype and adjustments to the growth constraint and husbandry factors. (EFG Broiler growth model, 1999).

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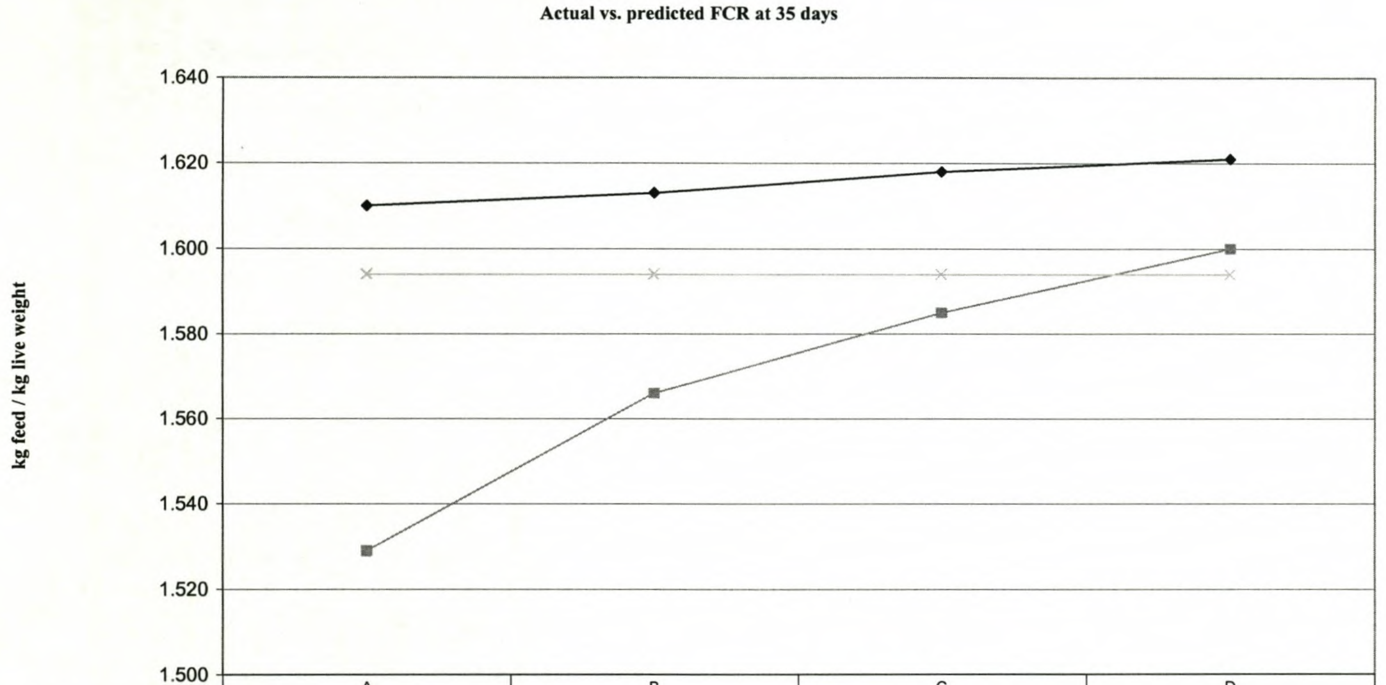

	A	B	C	D
Pred FCR (kg/kg)	1.610	1.613	1.618	1.621
Actual FCR (kg/kg)	1.529	1.566	1.585	1.600
Potential FCR	1.594	1.594	1.594	1.594

Treatment

Figure 14 Actual, EFG-predicted and EFG-potential FCR (kg feed/kg live weight) at 35 days of age for Trial Two: amino acid concentration decreases in the finisher diets only, A=high and C=Low.

Potential growth data (weight, feed intake or FCR): Details of the potential growth of the broiler are calculated at the same time as the actual growth is simulated. For this calculation it is assumed that there are no limitations to growth except those imposed by the genotype and adjustments to the growth constraint and husbandry factors. (EFG Broiler growth model, 1999).

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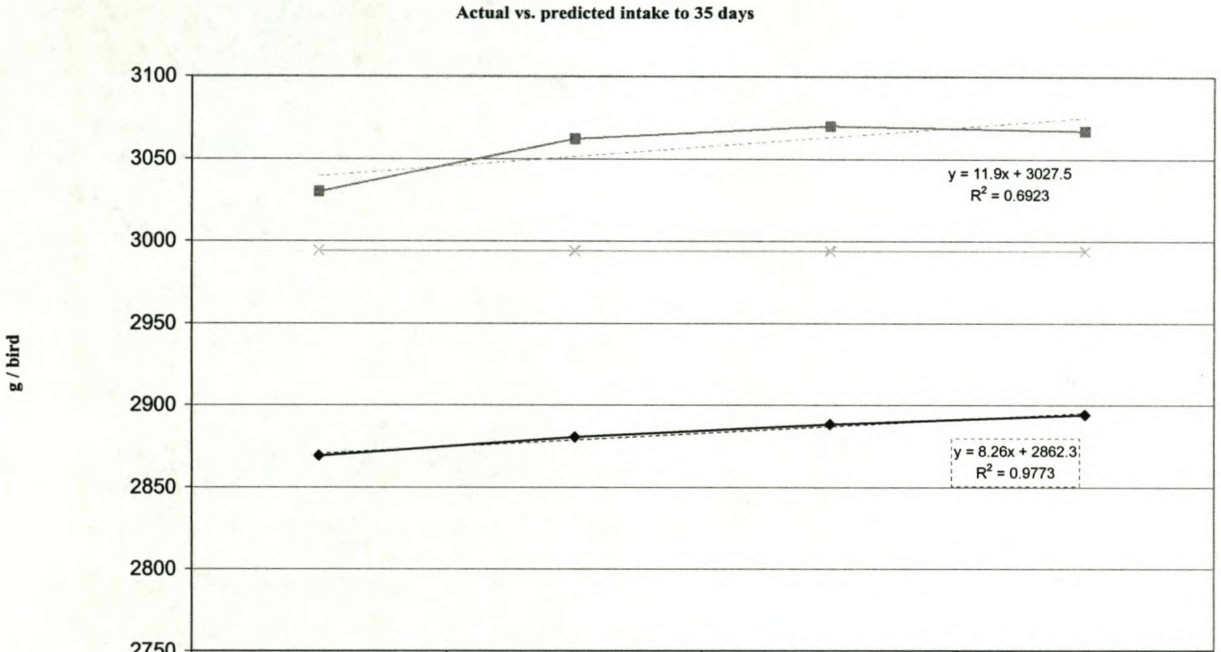

	A	B	C	D
Pred Intake (g)	2869	2880	2888	2894
Actual intake (g)	3030	3062	3070	3067
Potential Intake	2994	2994	2994	2994

Figure 15 Actual, EFG-predicted and EFG-potential intake (g/bird) at 35 days of age for Trial Two: amino acid concentration decreases in the finisher diets only, A=high and C=Low.

Potential growth data (weight, feed intake or FCR): Details of the potential growth of the broiler are calculated at the same time as the actual growth is simulated. For this calculation it is assumed that there are no limitations to growth except those imposed by the genotype and adjustments to the growth constraint and husbandry factors. (EFG Broiler growth model, 1999).

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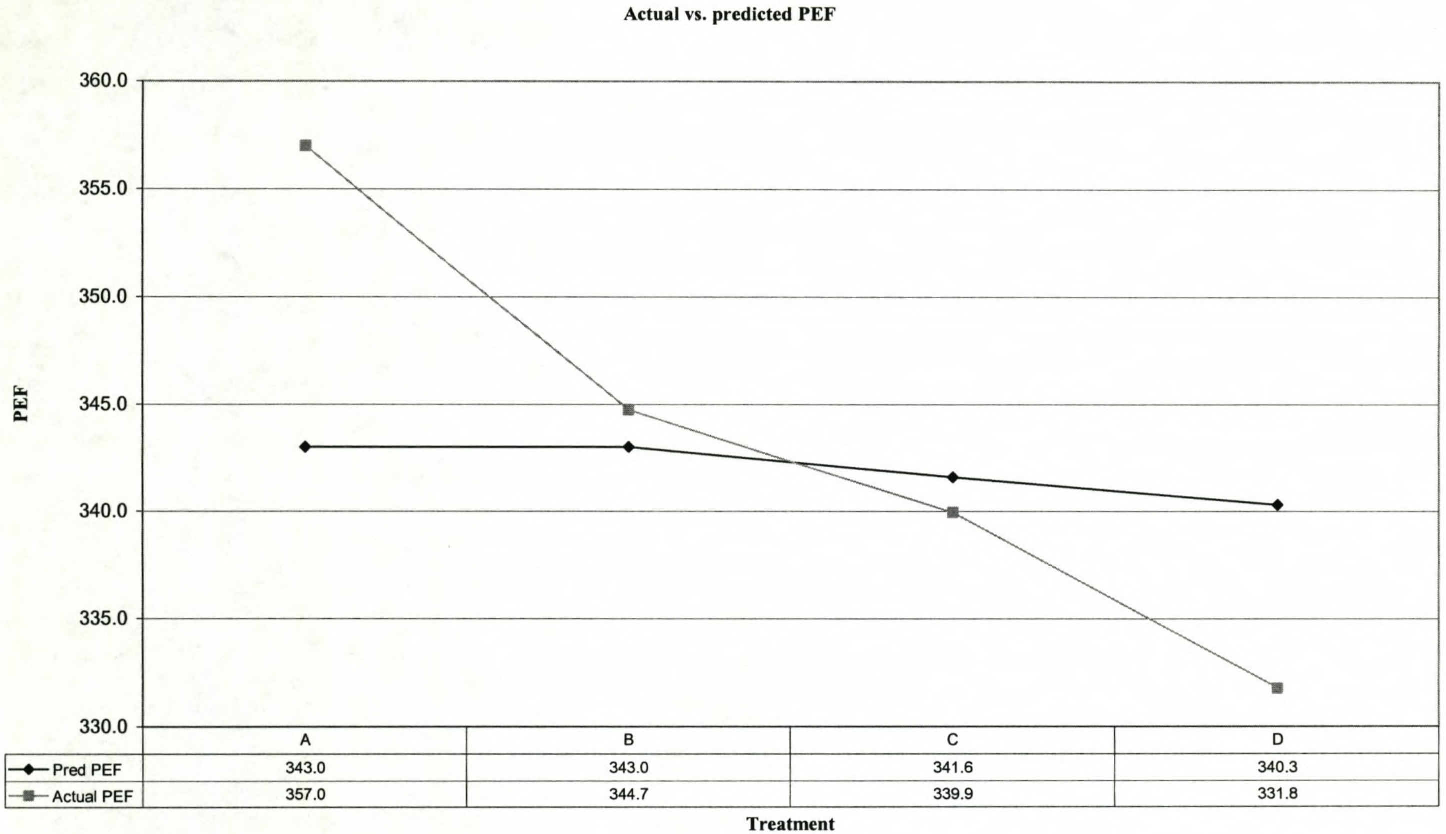

Figure 16 Actual vs. EFG-predicted PEF at 35 days of age for Trial Two: amino acid concentration decreases in the finisher diets only, A=high and C=Low.

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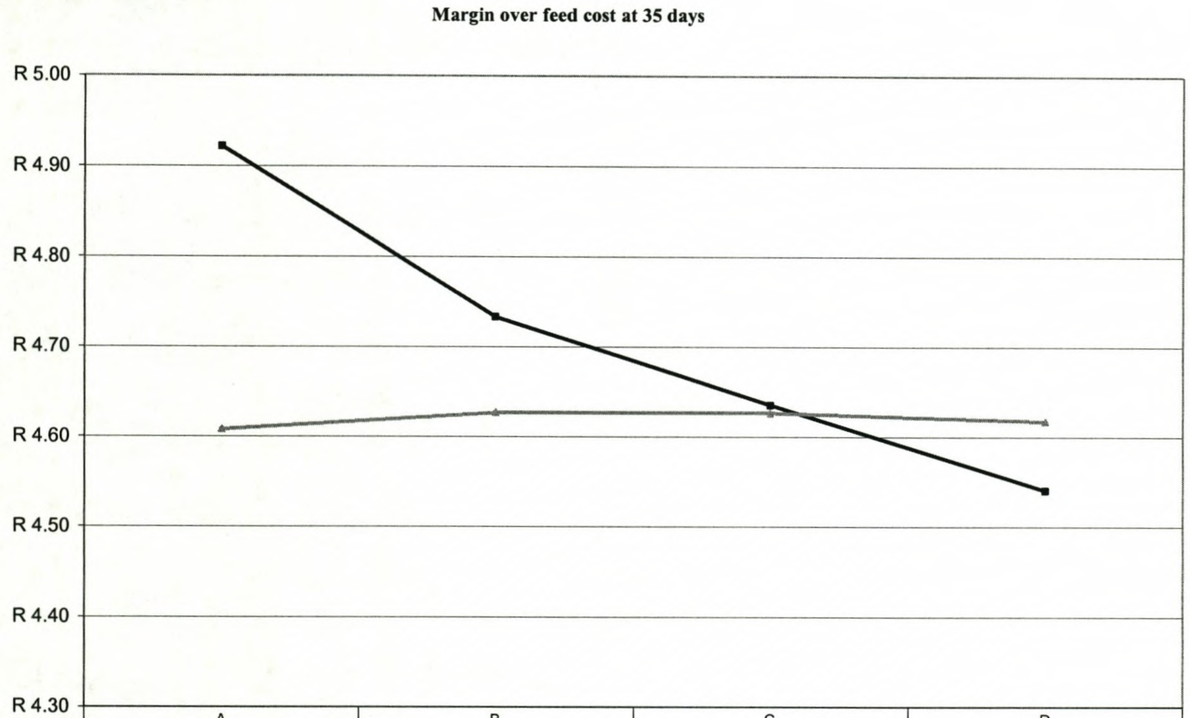

	A	B	C	D
Act Margin / feed cost	R 4.92	R 4.73	R 4.64	R 4.54
Pred Margin / feed cost	R 4.61	R 4.63	R 4.63	R 4.62

Figure 17 Actual vs. EFG-predicted margin over feed cost (R/bird) at 35 days of age for Trial Two: amino acid concentration decreases in the finisher diets only, A=high and C=Low.

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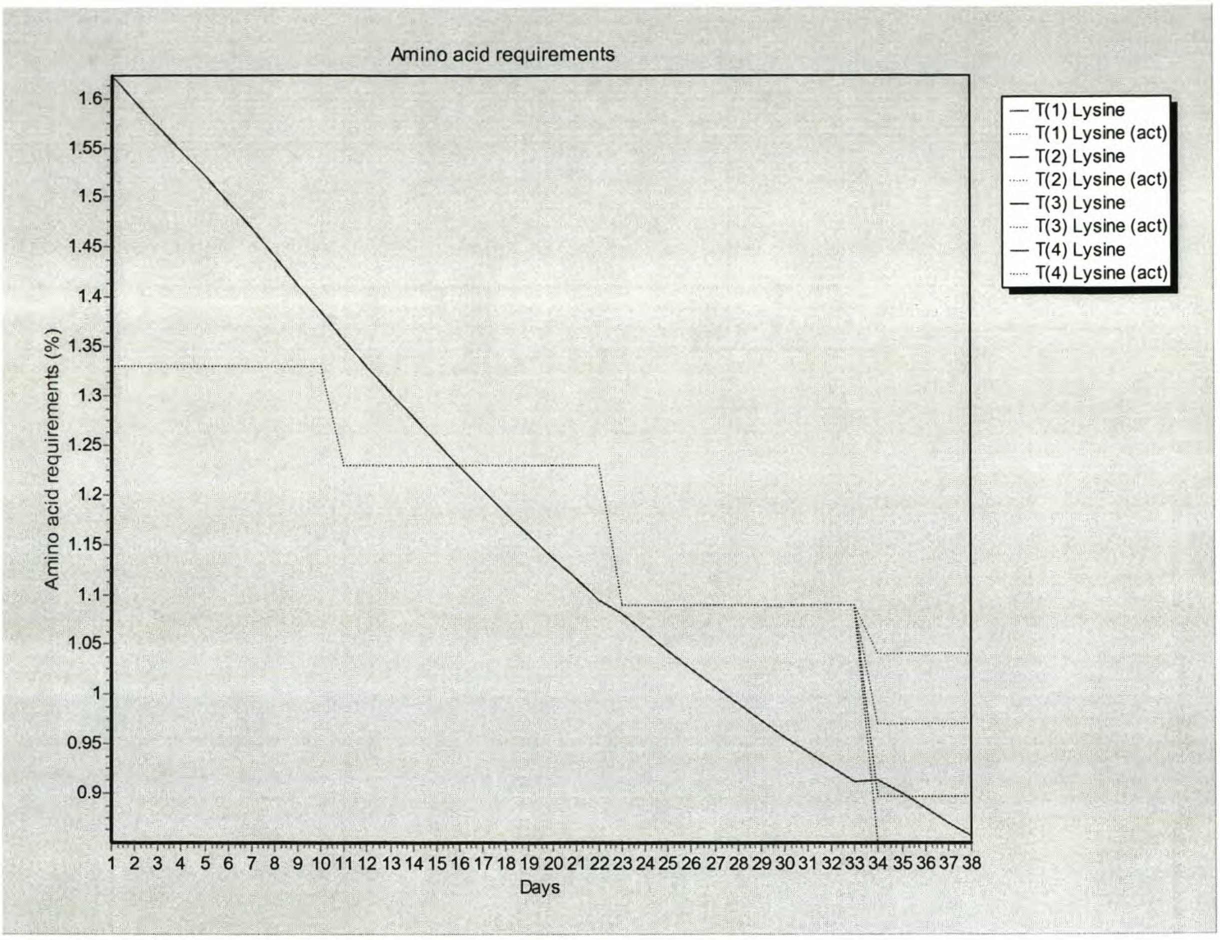

Figure 18 Digestible amino acid levels (%) for the four dietary treatments from day 1 to 38

The top stepped line represents the amino acid levels of treatment A, from pre-starter to finisher, and is indicated as T(1) in the graph. The stepped lines in the middle represents the amino acid levels of treatment B and C, from pre-starter to finisher, and is indicated as T(2) and T(3) in the graph.

The bottom stepped line represents the amino acid levels of treatment D, from pre-starter to finisher, and is indicated as T(4) in the graph.

The solid diagonal line represents the amino acid requirement from day 1 to 38.

Although the programme is indicated to 38 days, all calculations were made with data for day 35

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5. EFG SIMULATIONS BASED ON PUBLISHED DATA

Leeson *et al.,* (1996a) investigated the influence of dietary density in the finisher period on growth performance and carcass quality of broilers to 49 days of age. In experiment one, the same starter and grower diets were fed until day 16 and 35 respectively. Six diets with diluted energy densities were fed from 35 to 49 days of age.

In experiment two, the same starter and grower diets were used as for experiment one. Both energy and protein concentrations were diluted in experiment two.

Body weight, body weight gain, feed intake, energy intake, feed intake to body weight gain, carcass weight, breast weight and abdominal fat weight were measured for both experiments.

The diets given by Leeson *et al.,* (1996a) were formulated on Format (Format International, 2002) to calculate digestible lysine, ash and total fat values for each diet as they are required for the EFG simulation. The EFG broiler model was used to predict performance and carcass characteristics of these diets.

5.1 SIMULATION OF LITERATURE DATA: EXPERIMENT ONE

5.1.1 Results and discussion

The dietary composition of diets used in the first experiment (Leeson *et al.,* 1996a) is given in Table 14.

Table 14 Formulated nutrient analyses from published diets and feeding programmes used in the EFG-simulation for Experiment One (adapted from Leeson *et al.,* 1996a)

Feed	AMEn	Protein (%)	Dig Lys	Fat (%)	Water (%)	Ash (%)	Dig Lys (%) : ME (Mcal)	Age days
Starter	12.85	22.00	1.186	6.10	10.90	6.50	0.39	1-16
Grower	13.08	20.00	1.05	6.53	10.90	6.20	0.34	17-35
Finisher 1	13.44	18.00	0.91	7.58	10.84	5.90	0.28	36-49
Finisher 2	12.36	17.50	0.91	6.90	10.33	9.42	0.31	36-49
Finisher 3	11.30	17.00	0.91	6.20	9.82	12.99	0.34	36-49
Finisher 4	10.25	16.40	0.91	5.50	9.32	16.55	0.37	36-49
Finisher 5	9.21	16.00	0.91	4.80	8.81	20.12	0.41	36-49
Finisher 6	8.16	15.30	0.91	4.10	8.30	23.69	0.47	36-49

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Table 15 gives the predicted and actual weight gains as published by Leeson *et al.,* (1996a) vs. simulated values from the EFG broiler model for the period 35 to 49 days, as well as actual and predicted weights at 49 days.

Table 15 Actual weekly weight gains as published by Leeson *et al.,* (1996a) vs. simulated values from the EFG broiler model for the period 35 to 49 days, as well as actual and predicted weights at 49 days

	Weight gain (g)						Predicted Weight (g)	Actual weight (g)	Diff. Pred – Act.
	Pred 35-42 d	Act 35-42 d	Pred 42-49 d	Act 42-49 d	Pred 35-49 d	Act 35-49 d	49d	49 d	49 d
T1	581	567	582	612	1163	1179	2881	2982	-101
T2	579	574	568	603	1147	1177	2865	2998	-133
T3	560	571	541	599	1101	1170	2819	2970	-151
T4	541	512	512	582	1053	1094	2771	2913	-142
T5	520	515	495	699	1015	1214	2733	3022	-289
T6	498	465	483	669	981	1134	2699	2946	-247

Table 16 gives the predicted and actual feed intakes as published by Leeson *et al.,* (1996a) vs. simulated values from the EFG broiler model for the period 35 to 49 days.

Table 16 Actual weekly feed intakes as published by Leeson *et al.,* (1996a) vs. simulated values from the EFG broiler model for the period 35 to 49 days

	Pred 35-42 d (grams)	Act 35-42 d (grams)	Pred 42-49 d (grams)	Act 42-49 d (grams)	Pred 35-49 d (grams)	Act 35-49 d (grams)	Diff.(g) Pred. less Act. 35-49 d
T1	1314	1250	1419	1373	2733	2623	110
T2	1342	1301	1452	1401	2794	2702	92
T3	1355	1377	1480	1456	2835	2833	2
T4	1380	1371	1499	1585	2879	2956	-77
T5	1411	1444	1535	1677	2946	3121	-175
T6	1448	1482	1689	1946	3137	3427	-290
Difference: T6 less T1	134	232	270	573	404	804	-
Perc. Diff. (T6-T1)/T1	10.2	18.6	19.0	41.7	14.8	30.7	-

Body weight gains for predicted and actual values between 35 and 39 days followed the same downward trend from Treatment 1 to Treatment 4. (see Table 15, Figures 19 and 20) An increase in actual body weight and weight gain, relative to T1-T4, has been reported for T5 and T6. (see Table 15) Feed intake of these two treatments, however, did not increase to support the higher weight. This can be seen in Table 17, which shows the differences in weight gain and feed intake from one treatment to the following, for the whole period between 35 to 49 days. Table 17 shows that actual feed intake increased from T1 to T6. This was expected as energy density decreased by 250 kcal/kg or 1.05 MJ/kg between treatments. The body weight gain decreased by 79 g from T3–T4 in spite of a 123 g increase in feed intake. However, an actual

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increase in body weight of 120 g was measured between T4 and T5. Although feed intake increased by 165 g in this period, energy intake decreased steadily by ±5% between treatments. (see Table 18) One might argue that lysine intake increased because lysine concentration was the same in all finisher diets while intake increased between treatments. Actual lysine intake did increase, but the increase was a steady 4% between treatments (T1-5), and a 10% increase only between T5 and 6. (see Table 19) Thus, the increase in lysine intake was not bigger between T4 and T5 than between T3 and T4, although a significant increase in body weight was reported between T4 and T5. Table 17 shows the increase in feed intake required to maintain equal energy intake. Neither the actual nor predicted increments in feed intake come close to this required intake. The predicted lower body weight gains are a logical result of the predicted and actual decrease in energy intake, but the reported increase in weight gains from T4 to 5, as well as the final weight for T6 that is higher than T4, is difficult to explain.

It is further interesting to note that the predicted increase in feed intake from T1 to T6 is 404 g (+14.8%) while it is 804 g (30.7%) for actual values. (see Table 16) When actual and predicted intakes are compared between 35 and 49 days, predicted intakes are 110 g higher than actual for T1 but 290 g lower than actual for T6 (Table 16). The capacity of the birds to increase feed intake must be emphasised.

Table 17 The differences in dietary energy and digestible lysine density as well as weight gain and feed intake (i.e. EFG-predicted and actual) from one treatment to the following, for the whole period between 35 and 49 days

	From T1 to T2	From T2 to T3	From T3 toT4	From T4 toT5	From T5 toT6
Difference in energy density (MJ/kg) of finisher diets between treatments	-1.05	-1.05	-1.05	-1.05	-1.05
Difference in digestible Lys density (%) of finisher diets between treatments	0	0	0	0	0
Difference in actual weight gain (g) between treatments between 35 and 49 days	-2	-7	-79	+120	-80
Difference in predicted weight gain (g) between treatments between 35 and 49 days	-16	-46	-48	-38	-34
Actual increased feed intake (g) between treatments from 35 to 49 days	+79	+131	+123	+165	+306
Predicted increased feed intake between treatments (g) from 35 to 49 days	+61	+41	+44	+67	+191
Increased feed intake required between treatments to maintain equal energy intake (g) from 35 to 49 days*	+229	+268	+319	+390	+491

(* Although a constant 1.05MJ ME is taken away between treatments, the 1.05 becomes a bigger portion of the total energy. Therefore, feed intake increases exponentially to compensate for the lower ME concentration).

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Table 18 Formulated energy concentration (MJ ME/kg feed) as well as weekly EFG-predicted and actual energy intake (calculated from Leeson *et al.*, 1996a) for each treatment from 35 to 49 days of age

		ME intake (MJ / bird)						
Treat-ment	MJ ME/kg feed	Pred 35-42d	Act 35-42d	Pred 42-49d	Act 42-49d	Pred 35-49d	Act 35-49d	Percentage of previous Act 35-49d
T1	13.44	17.66	16.80	19.07	18.45	36.73	35.25	-
T2	12.36	16.59	16.08	17.95	17.32	34.53	33.40	94.8
T3	11.30	15.31	15.56	16.72	16.45	32.03	32.00	95.8
T4	10.25	14.15	14.05	15.36	16.25	29.51	30.30	94.7
T5	9.21	12.99	13.29	14.13	15.44	27.12	28.73	94.8
T6	8.16	11.81	12.09	13.78	15.88	25.59	27.96	97.3

Table 19 Formulated digestible lysine concentration (% of diet) as well as weekly EFG-predicted and actual digestible lysine intake (calculated from Leeson *et al.*, 1996a) for each treatment from 35 to 49 days

Treat-ment			Dig Lys intake (g/bird)					Percentage of previous Act 35-49d
	Dlys/kg feed	Pred 35-42d	Act 35-42d	Pred 42-49d	Act 42-49d	Pred 35-49d	Act 35-49d	
T1	0.91	11.97	11.39	12.93	12.51	24.90	23.90	-
T2	0.91	12.23	11.85	13.23	12.76	25.45	24.62	103.9
T3	0.91	12.34	12.55	13.48	13.26	25.83	25.81	104.8
T4	0.91	12.57	12.49	13.66	14.44	26.23	26.93	104.3
T5	0.91	12.85	13.16	13.98	15.28	26.84	28.43	105.0
T6	0.91	13.19	13.50	15.39	17.73	28.58	31.22	109.8

Correlation coefficients have been calculated for a number of factors. Table 20 summarises the correlation coefficient (R) for the current simulation.

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Table 20 Correlation coefficients for weight gain, energy intake, feed intake, FCR and carcass traits between actual and EFG-predicted values for Experiment One

	42 d	49 d	35-42 d	42-49 d	35-49 d
Weight T1-6 (g)	0.9593	0.2453			
Weight gain T1-6 (g)	-0.6175	0.2503			
Weight 1-4 (g)		0.9100			
Weight gain T1-4 (g)	0.9721	0.8940			
Energy intake (kcal)					0.9986
Feed intake T1-6 (g)			0.9662	0.9816	0.9914
Feed intake T1-4 (g)					0.9812
FCR T1-6 (g/g)			0.9940	0.8468	0.9511
FCR T1-4 (g/g)				0.9725	0.9825
Carcass percentage (%)	0.7859	0.7561			
Fat (g)	0.9523	0.9422			
Fat (%)	0.9260	0.9059			
Breast meat (%)	0.0066	0.0179			

Table 20 shows that the correlation (R) between actual and predicted weight/weight gain is much better for T1-4 than T1-6. The correlation of feed intake, however, was not influenced when calculated for T1-4 or T1-6. Should T5 and T6 be ignored, the correlation coefficients indicate a good simulation of body weight and body weight gain. These values again put a question mark behind the reported weights for T5 and T6.

Good correlation coefficients (R>0.90) were obtained for feed and energy intake. (Table 20, Figures 21 and 27) The prediction of FCR was influenced by the reported weights. (see Figure 22)

Figures 19 to 27 illustrate the comparisons between actual and predicted results.

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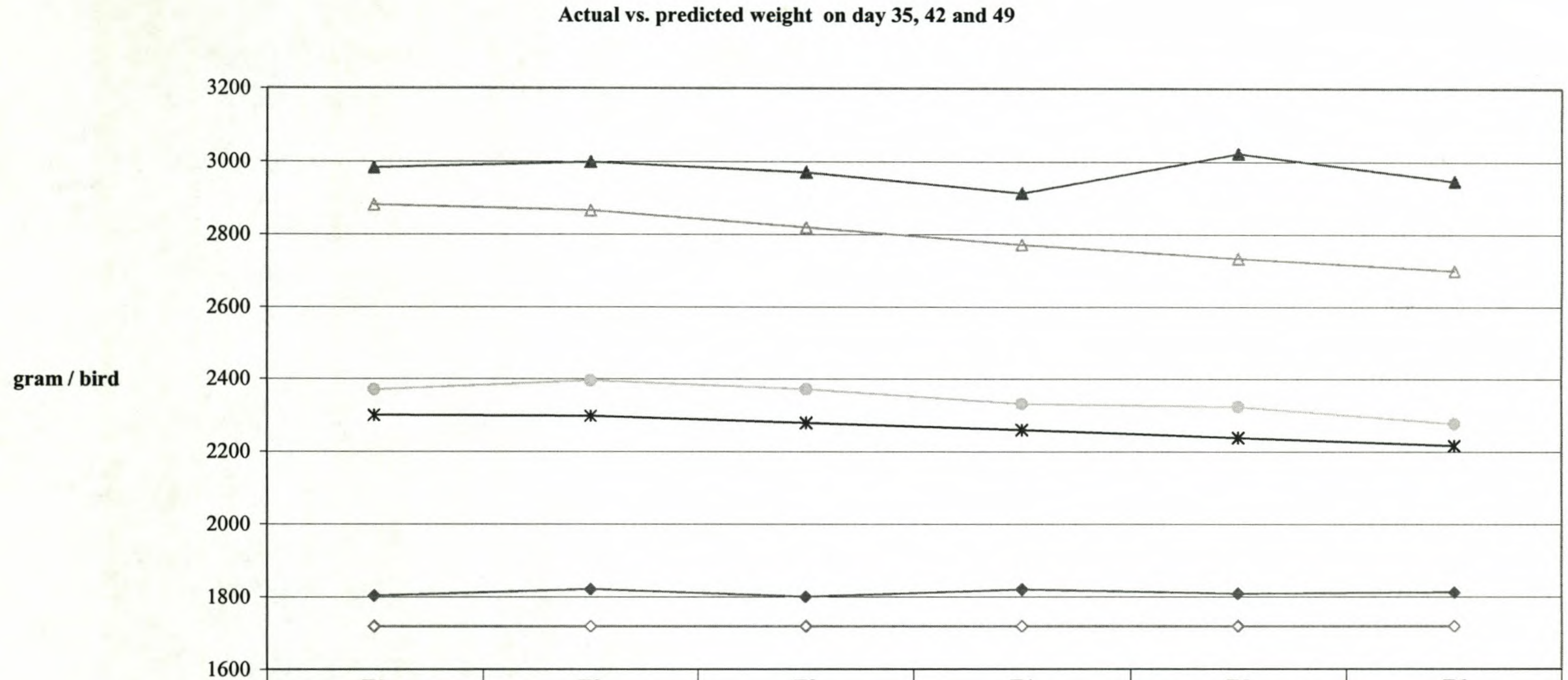

	T1	T2	T3	T4	T5	T6
Pred 35d	1718	1718	1718	1718	1718	1718
Pred 42d	2299	2297	2278	2259	2238	2216
Act 42d	2370	2395	2371	2331	2323	2277
Pred 49d	2881	2865	2819	2771	2733	2699
Act 49d	2982	2998	2970	2913	3022	2946
Act 35d	1803	1821	1800	1819	1808	1812

Figure 19 Actual vs. EFG-predicted weights (g/bird) at 35, 42 and 49 days of age where finisher diets differing only in energy concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

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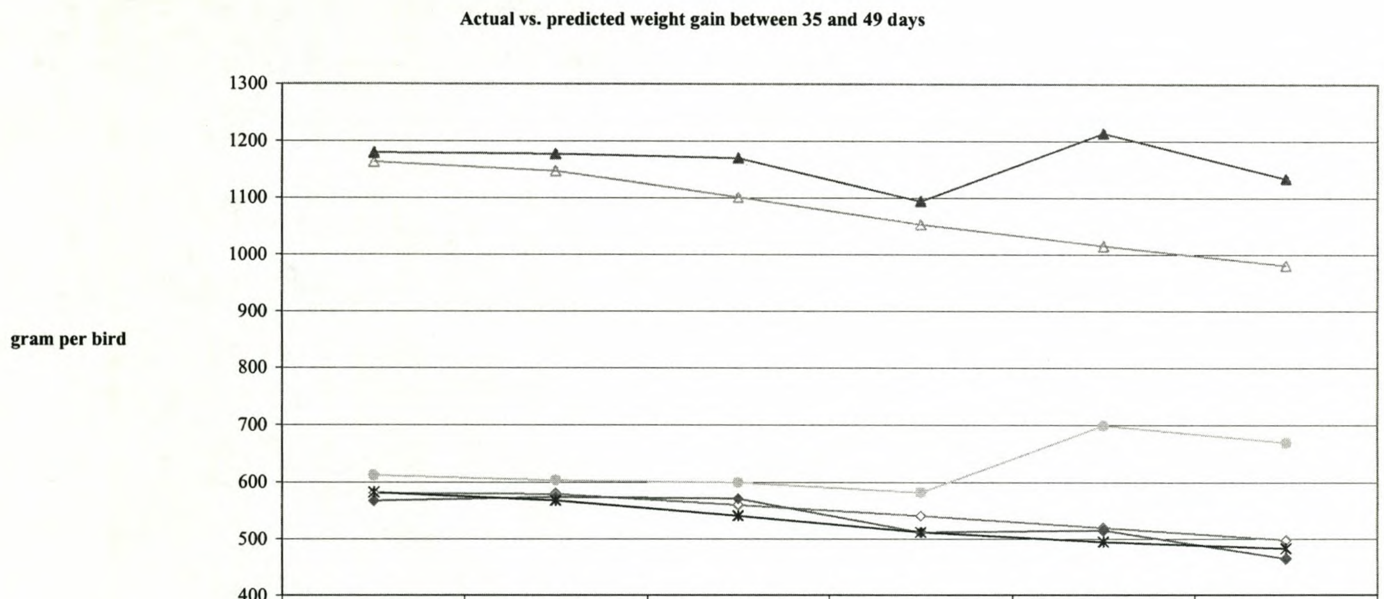

	T1	T2	T3	T4	T5	T6
Pred 35-42d	581	579	560	541	520	498
Act 35-42d	567	574	571	512	515	465
Pred 42-49d	582	568	541	512	495	483
Act 42-49d	612	603	599	582	699	669
Pred 35-49d	1163	1147	1101	1053	1015	981
Act 35-49d	1179	1177	1170	1094	1214	1134

Figure 20 Actual vs. EFG-predicted weight gain (g/bird) between 35-42, 42-49 and 35-49 days of age where finisher diets differing only in energy concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

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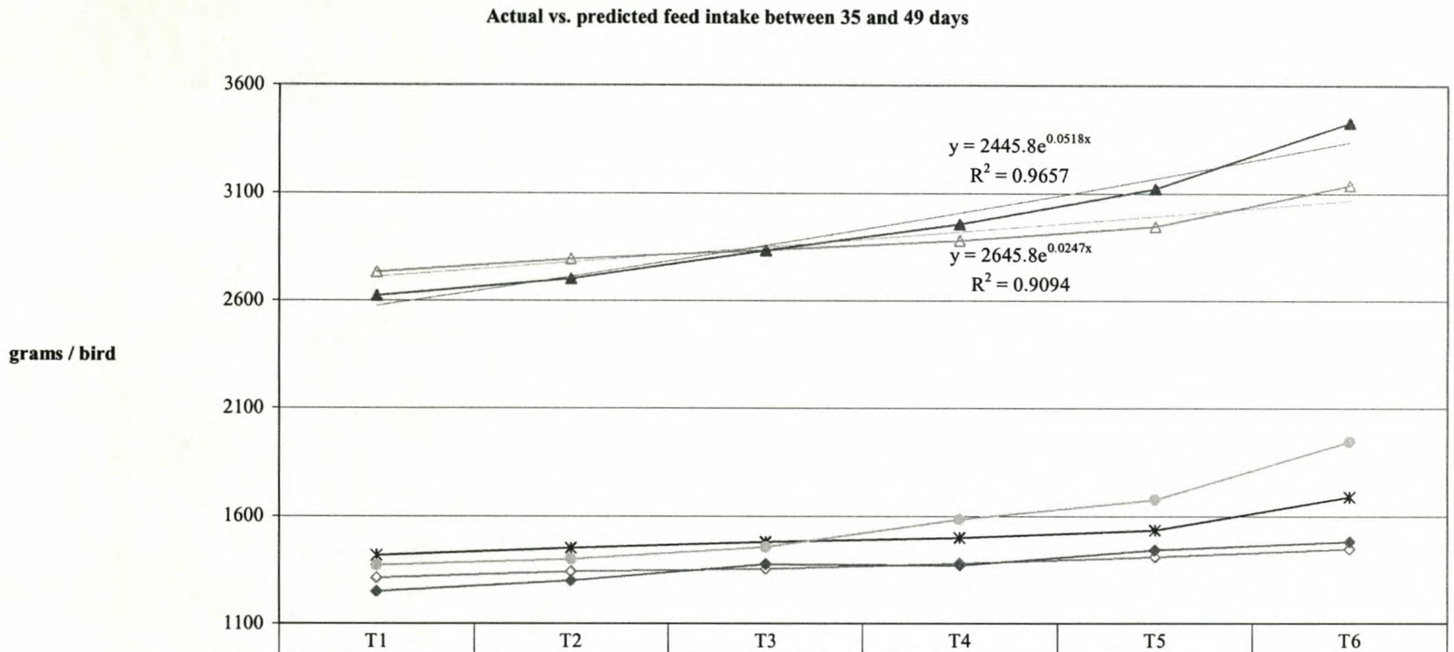

	T1	T2	T3	T4	T5	T6
Pred 35-42d	1314	1342	1355	1380	1411	1448
Act 35-42d	1250	1301	1377	1371	1444	1482
Pred 42-49d	1419	1452	1480	1499	1535	1689
Act 42-49d	1373	1401	1456	1585	1677	1946
Pred 35-49d	2733	2794	2835	2879	2946	3137
Act 35-49d	2623	2702	2833	2956	3121	3427

Figure 21 Actual vs. EFG-predicted feed intake (g/bird) between 35-42, 42-49 and 35-49 days of age where finisher diets differing only in energy concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

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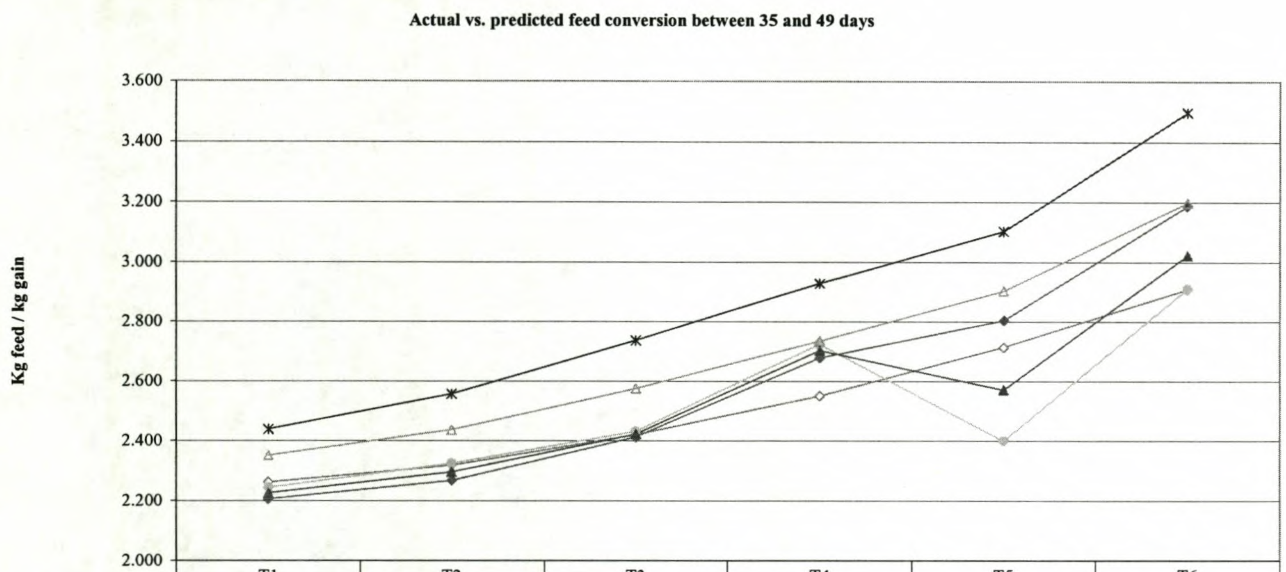

	T1	T2	T3	T4	T5	T6
Pred 35-42d	2.262	2.318	2.420	2.551	2.713	2.908
Act 35-42d	2.205	2.267	2.412	2.678	2.804	3.187
Pred 42-49d	2.438	2.556	2.736	2.928	3.101	3.497
Act 42-49d	2.243	2.323	2.431	2.723	2.399	2.909
Pred 35-49d	2.350	2.436	2.575	2.734	2.902	3.198
Act 35-49d	2.225	2.296	2.421	2.702	2.571	3.022

Figure 22 Actual vs. EFG-predicted FCR (kg feed / kg live weight) between 35-42, 42-49 and 35-49 days of age where finisher diets differing only in energy concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

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Figures 23 to 26 illustrate the actual vs. predicted carcass data. The predicted carcass percentage (Figure 23) and percentage breast meat (Figure 26) increased with a decrease in energy intake. Actual percentage carcass and breast meat, however, did not follow the expected trends. Poor correlations were obtained for breast meat percentage and carcass percentage. (see Table 20) The reason for this is not clear, but moisture loss during analysis could have influenced results.

As expected, the predicted and actual percentage carcass fat (Figure 25) decreases as energy intake decreases from T1 to T6. (see Figure 27) Good correlation coefficients (R>0.90) were obtained for fat content of birds fed the six different diets (Table 20). Linear regression lines were fitted for actual and predicted fat values (i.e. in g and as percentage). (see Figures 24 and 25) In both instances the predicted values decreased more rapidly than actual values, as seen from the x-coefficients in Figures 24 and 25 (e.g. -9.96 vs. –3 for 49 day predicted and actual values respectively in Fig 24). Schutte & Pack, 1995, Si *et al.*, 2001 and Sklan & Plavnik, 2002 also observed that carcass fat decreases as the protein:energy ratios increase. The digestible lysine (%): metabolizable energy (Mkal) for T1-6 is calculated as 0.25, 0.27, 0.30, 0.33, 0.37 and 0.42 respectively.

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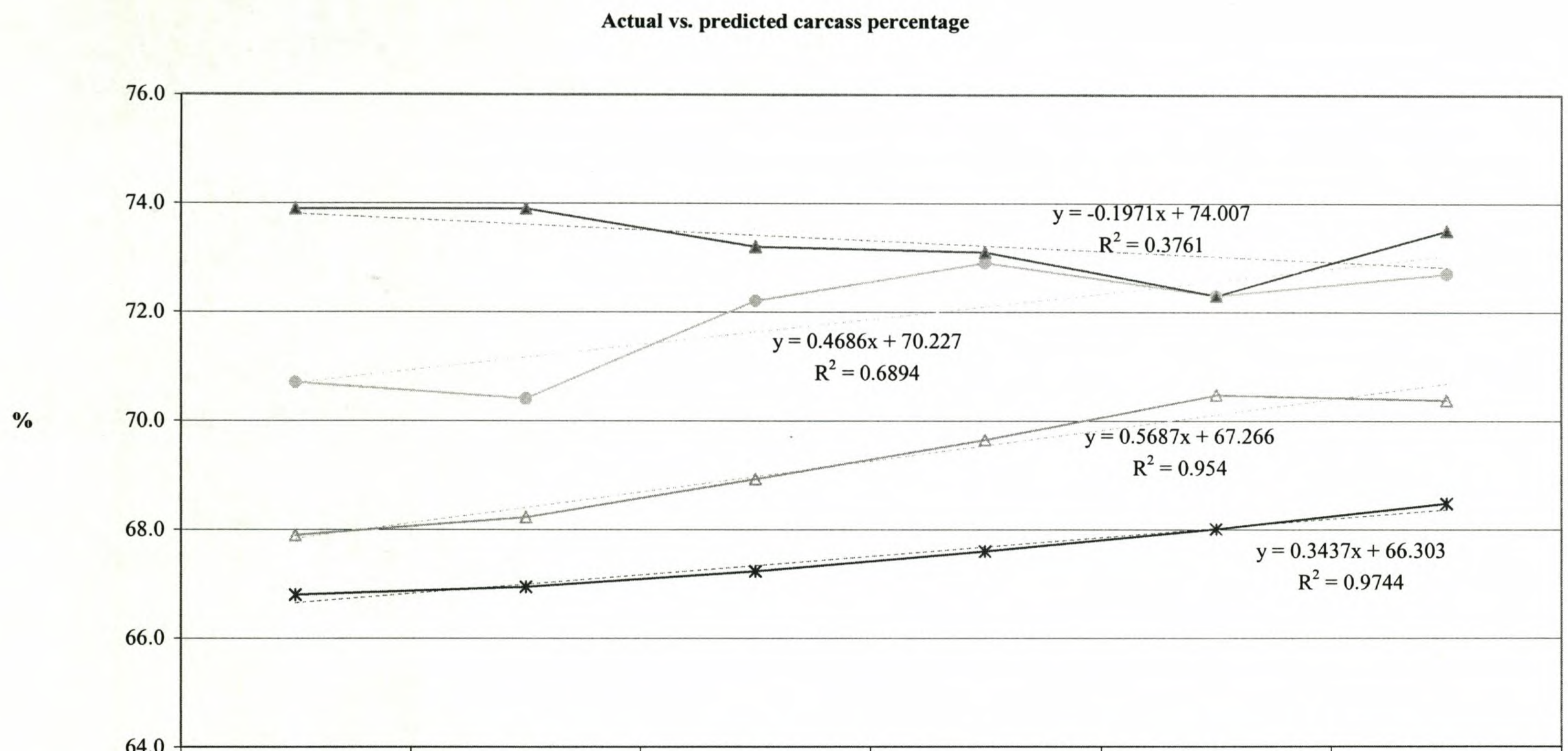

	T1	T2	T3	T4	T5	T6
Pred 42d	66.8	66.9	67.2	67.6	68.0	68.5
Act 42d	70.7	70.4	72.2	72.9	72.3	72.7
Pred 49d	67.9	68.2	68.9	69.6	70.5	70.4
Act 49d	73.9	73.9	73.2	73.1	72.3	73.5

Figure 23 Actual vs. EFG-predicted carcass percentage at 42 and 49 days of age where finisher diets differing only in energy concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

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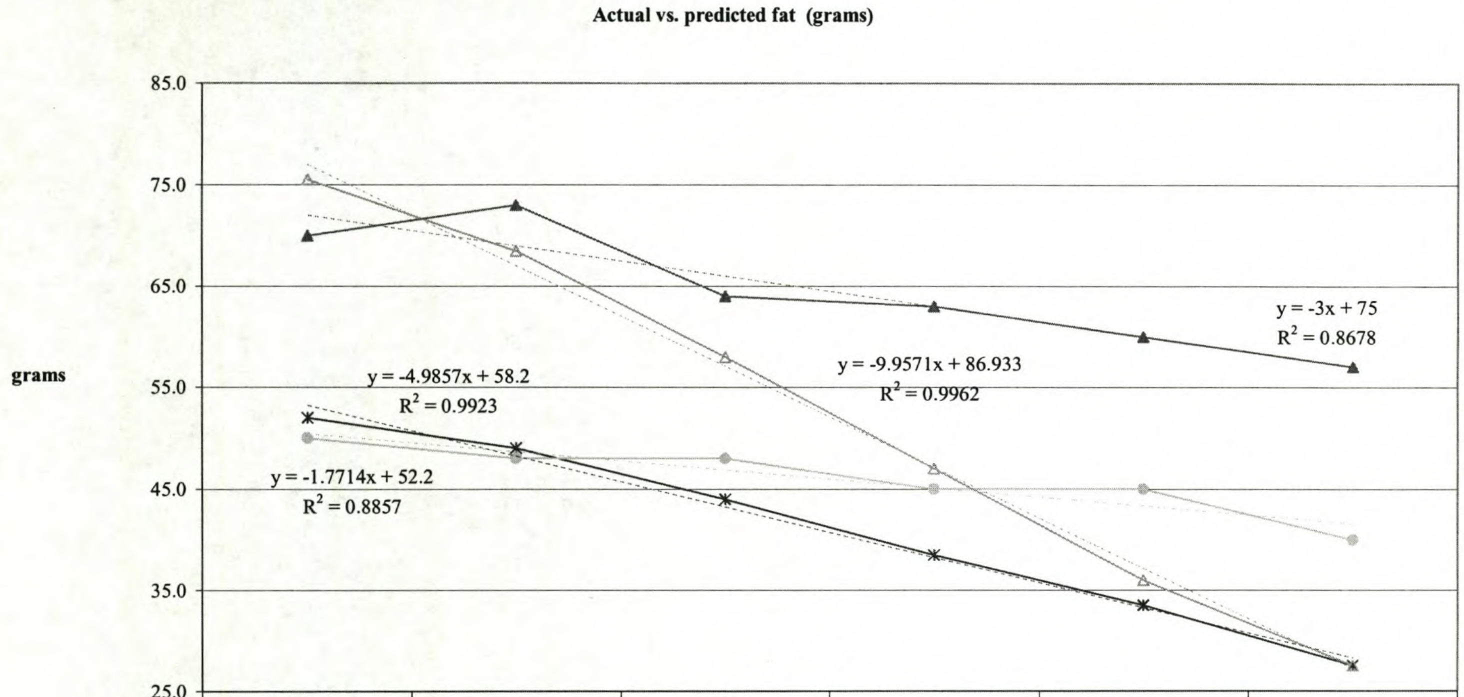

	T1	T2	T3	T4	T5	T6
Pred 42d	52.0	49.0	44.0	38.5	33.5	27.5
Act 42d	50.0	48.0	48.0	45.0	45.0	40.0
Pred 49d	75.5	68.5	58.0	47.0	36.0	27.5
Act 49d	70.0	73.0	64.0	63.0	60.0	57.0

Figure 24 Actual vs. EFG-predicted fat (g/bird) at 42 and 49 days of age where finisher diets differing only in energy concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

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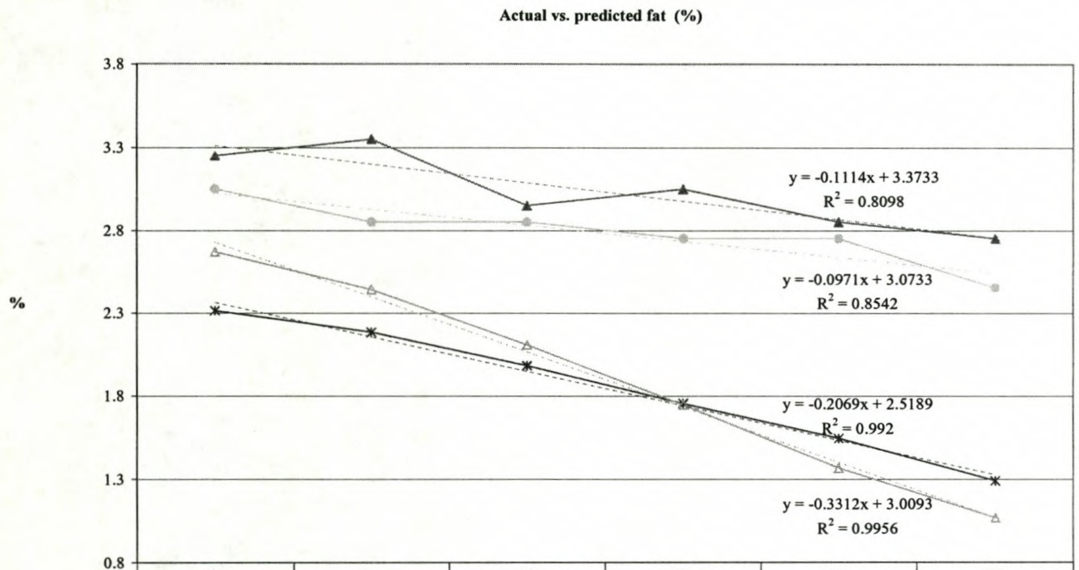

	T1	T2	T3	T4	T5	T6
Pred 42d	2.3	2.1	1.9	1.7	1.5	1.2
Act 42d	3.0	2.8	2.8	2.7	2.7	2.4
Pred 49d	2.6	2.4	2.1	1.7	1.3	1.0
Act 49d	3.2	3.3	2.9	3.0	2.8	2.7

Figure 25 Actual vs. EFG-predicted percentage fat at 42 and 49 days of age where finisher diets differing only in energy concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

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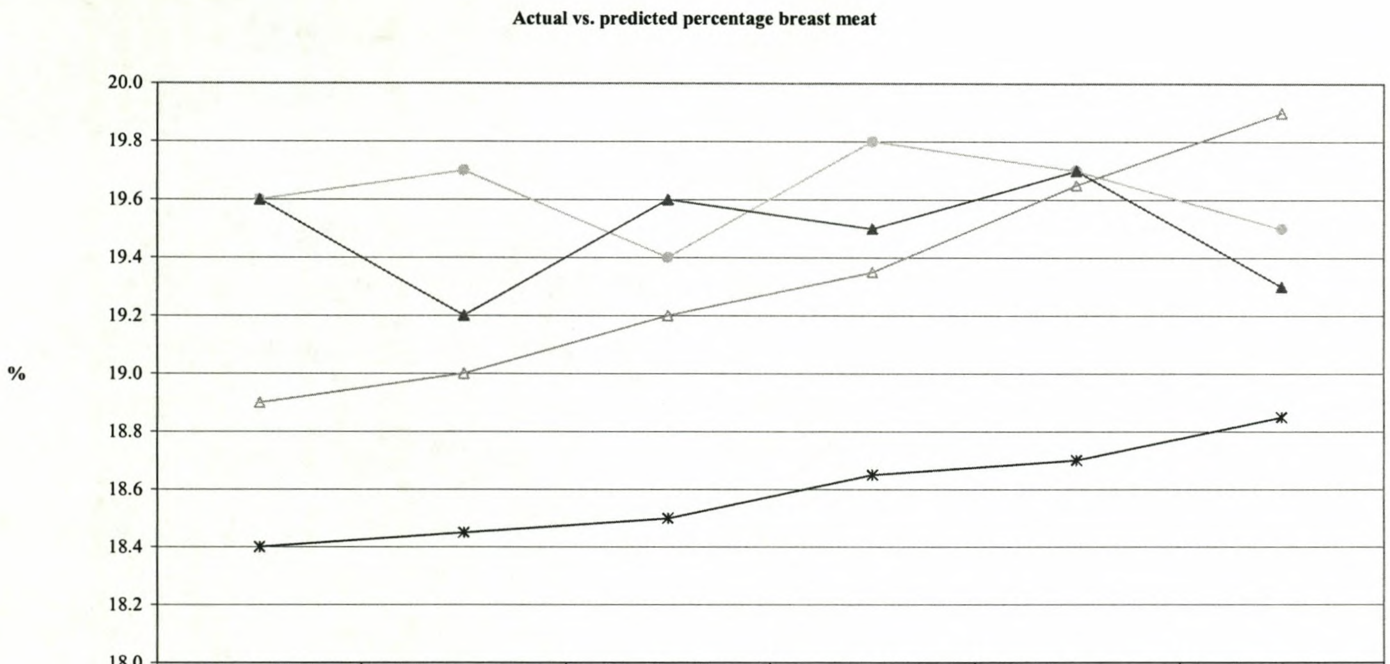
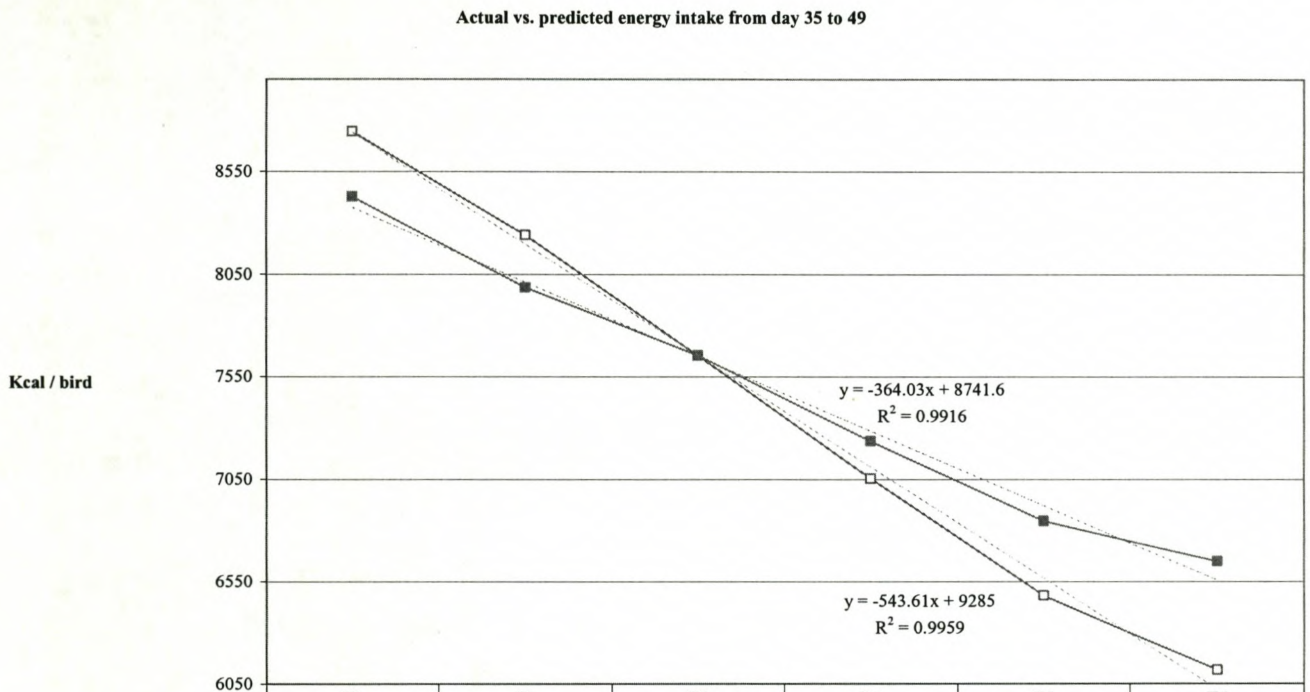


	T1	T2	T3	T4	T5	T6
Pred 42d	18.4	18.5	18.5	18.7	18.7	18.9
Act 42d	19.6	19.7	19.4	19.8	19.7	19.5
Pred 49d	18.9	19.0	19.2	19.4	19.7	19.9
Act 49d	19.6	19.2	19.6	19.5	19.7	19.3

Figure 26 Actual vs. EFG-predicted percentage breast meat at 42 and 49 days of age where finisher diets differing only in energy concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)



	T1	T2	T3	T4	T5	T6
Pred ME Intake	8746	8242	7655	7054	6481	6117
Act ME intake	8429	7988	7655	7237	6847	6649

Figure 27 Actual vs. EFG-predicted energy intake between 35 and 49 days of age where finisher diets differing only in energy concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

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5.2 SIMULATION OF LITERATURE DATA: EXPERIMENT TWO

In experiment two of Leeson *et al.,* (1996a) the same starter and grower diets were used as for experiment one. In experiment one, only energy concentration was diluted, but both energy and protein concentrations were diluted in experiment two. Body weight, body weight gain, feed intake, energy intake, feed intake to body weight gain, carcass weight, breast weight and abdominal fat weight were measured for experiment two.

The diets given by Leeson *et al.,* (1996a) were formulated on Format (Format International, 2002) to calculate digestible lysine, ash and total fat values for each diet, as they are required for the EFG simulation. The EFG broiler model was used to predict performance and carcass characteristics of these diets.

5.1.2 Results and discussion

The dietary composition of diets used in the second experiment (Leeson *et al.,* 1996a) is given in Table 21.

Table 21 Formulated nutrient analyses from published diets and feeding programmes used in the EFG-simulation for Experiment Two (adapted from Leeson *et al.,* 1996a)

Feed	AMEn	Protein (%)	Fat (%)	Dig. Lys (%)	Water (%)	Ash (%)	Carboh. (%)	Dig Lys (%) : ME (Mcal)	Age (days)
Starter	12.85	22.00	6.10	1.19	10.90	6.50	54.50	0.39	1-16
Grower	13.08	20.00	6.53	1.05	10.90	6.20	56.37	0.34	17-35
Finisher 1	13.44	18.00	7.58	0.91	10.84	5.90	57.68	0.28	36-49
Finisher 2	12.09	16.20	6.90	0.82	10.15	10.60	56.15	0.28	36-49
Finisher 3	10.75	14.40	6.20	0.73	9.50	15.40	54.50	0.28	36-49
Finisher 4	9.41	12.60	5.40	0.64	8.75	20.14	53.11	0.28	36-49
Finisher 5	8.05	10.80	4.60	0.55	8.05	24.90	51.65	0.29	36-49
Finisher 6	6.72	9.00	3.90	0.46	7.36	29.60	50.14	0.29	36-49

Table 22 gives the predicted and actual weight gains as published by Leeson *et al.,* (1996a) vs. simulated values from the EFG broiler model for the period 35 to 49 days, as well as actual and predicted weights at 49 days.

Table 22 Actual weekly weight gains as published by Leeson *et al.,* (1996a) vs. simulated values from the EFG broiler model for the period 35 to 49 days, as well as actual and predicted weights at 49 days

	Weight gain (gram/bird)						Predicted weight (g/b)	Actual weight (g/b)	Diff. Pred – Act.
	Pred 35-42	Act 35-42 d	Pred 42-49 d	Act 42-49 d	Pred 35-49 d	Act 35-49 d	49 Days	49 Days	
T1	581	580	582	528	1163	1107	2881	2948	-67
T2	586	556	573	554	1159	1110	2877	2921	-44
T3	593	511	564	559	1157	1071	2875	2879	-4
T4	597	448	547	650	1144	1098	2862	2913	-51
T5	588	370	508	743	1096	1112	2814	2913	-99
T6	566	404	456	674	1022	1077	2740	2892	-152

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Table 23 gives the predicted and actual feed intakes as published by Leeson *et al.,* (1996a) vs. simulated values from the EFG broiler model for the period 35 to 49 days.

Table 23 Actual weekly feed intakes as published by Leeson *et al.,* (1996a) vs. simulated values from the EFG broiler model for the period 35 to 49 days

	Feed intake (Gram/bird)						**Diff. Pred less Act. (g)**
	Pred 35-42	**Act 35-42 d**	**Pred 42-49 d**	**Act 42-49 d**	**Pred 35-49 d**	**Act 35-49 d**	**35 – 49 d**
T1	1313	1284	1420	1299	2733	2583	150
T2	1400	1318	1508	1445	2908	2763	145
T3	1559	1387	1680	1517	3239	2904	335
T4	1754	1429	1881	1844	3635	3273	362
T5	1977	1472	2095	2201	4072	3673	399
T6	2236	1685	2340	2610	4576	4295	281
Difference: T6 less T1	923	401	920	1311	1843	1712	-
Perc. Diff. (T6-T1)/T1	70.3	31.2	64.8	100.9	67.4	66.3	-

In the period between 35 and 42 days the predicted weight gain for T1 to T6 increased slightly before decreasing again. Actual weight decreased from T1 to T6 in this period. For the period 42 to 49 days, predicted weight decreased steadily while actual weight between T3- T4 and T4-T5 increased substantially (Table 22, Figures 28 and 29). As mentioned in the discussion of the previous experiment, none of feed intake (Table 24, Figure 30), energy intake (Table 25, Figure 36) or lysine intake (Table 26) supports the reported increased weight gains. Table 24 also shows the increase in weight gain for T4 and T5, but actual increase in feed intake is lower than the required increase in feed intake to keep energy and lysine intake constant.

It is, however, important to compare the increase in feed intake (T6 less T1) measured in the first literature simulation (Table 16) with the values in Table 23. In experiment one, actual and predicted feed intake increased by 804 g (+30.7%) and 404 g (+14.8%) respectively (i.e. T6 less T1, 35 to 49 days). In this period, energy intake decreased by ±5% while digestible lysine intake increased by ±5% (Table 18 and 19).

In experiment two, actual energy as well as digestible lysine intake decreased by ±4% between treatments from 35 to 49 days. (Table 25 and 26) The actual and predicted increase in intake (T6 less T1, 35 to 49 days) was 1712 g (+66.2%) and 1843 g (+67.0%). (Table 23) Compared to values given above for experiment one, there was a significant increase in feed intake (actual and predicted) for experiment two. The initial actual intake for treatment one differed by only 37 g between experiments one and two, thus the differences mentioned above are not due to an initial difference in intake. It may be argued that the decrease in energy concentration between treatments was larger for treatment two than for treatment one (1.35 vs. 1.05 MJ ME/kg). Regression coefficients were calculated for energy concentration vs. feed intake for experiment one and two. The following regressions were obtained:

Experiment one: $y = 154.3x + 2403.7$ ($R^2 = 0.95$)
Experiment two: $y = 333.1x + 2082.6$ ($R^2 = 0.94$)
With y = feed intake in grams per bird and x = energy concentration in MJ ME / kg feed

In experiment two, feed intake increased by 333.1 g for each mega joule increase in energy concentration.

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The increase was more than double the value of 154.3 calculated for experiment one. If energy concentration alone controlled feed intake, one would have expected the x-coefficients to be more or less the same. This leads to the conclusion that energy intake alone does not influence feed intake, but that amino acid density also plays a significant role. The extreme nature of the diets must, however, be noted here.

The differences in weight gain and feed intake from one treatment to the following for the whole period between 35 to 49 days are given in Table 24.

Table 24 The differences in dietary energy and digestible lysine density as well as weight gain and feed intake (i.e. EFG-predicted and actual) from one treatment to the following, for the whole period between 35 and 49 days

	T1-T2	T2-T3	T3-T4	T4-T5	T5-T6
Difference in energy density (MJ/kg) of finisher diets between treatments	-1.35	-1.35	-1.35	-1.35	-1.35
Difference in digestible Lys density (%) of finisher diets between treatments	-0.09	-0.09	-0.09	-0.09	-0.09
Difference in actual weight gain (g) between treatments between 35 and 49 days	+3	-39	+27	+14	-35
Difference in predicted weight gain (g) between treatments between 35 and 49 days	-4	-2	-13	-48	-74
Difference in actual intake between treatments from 35 to 49 days (g)	+180	+141	+369	+400	+622
Difference in predicted intake between treatments from 35 to 49 days (g)	+175	+331	+396	+437	+504
Increased intake required for equal digestible Lys intake (g) between 35-49 days (g)	+277	+352	+462	+610	+864
Increased intake required for equal energy intake (g) between 35-49 days (g)	+288	+358	+459	+623	+860

Table 25 Formulated energy concentration (MJ ME/kg feed) as well as weekly EFG-predicted and actual energy intake (calculated from Leeson *et al.*, 1996a) for each treatment from 35 to 49 days of age

			ME intake (MJ/bid)					
Treat-ment	MJ ME / kg feed	Pred 35-42d	Act 35-42d	Pred 42-49d	Act 42-49d	Pred 35-49d	Act 35-49d	Percentage of previous Act 35-49d
T1	13.44	17.65	17.26	19.08	17.46	36.73	34.72	
T2	12.09	16.93	15.94	18.23	17.47	35.16	33.41	96.2
T3	10.75	16.76	14.91	18.07	16.31	34.83	31.23	93.5
T4	9.41	16.51	13.45	17.71	17.36	34.22	30.81	98.7
T5	8.05	15.92	11.86	16.87	17.73	32.80	29.58	96.0
T6	6.72	15.01	11.31	15.71	17.53	30.73	28.84	97.5

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Table 26 Formulated digestible lysine concentration (% of diet) as well as weekly EFG-predicted and actual digestible lysine intake (calculated from Leeson *et al.*, 1996a) for each treatment from 35 to 49 days

		Intake Dlys (g)						
Treat-ment	**DLys (% feed)**	**Pred 35-42d**	**Act 35-42d**	**Pred 42-49d**	**Act 42-49d**	**Pred 35-49d**	**Act 35-49d**	**Percentage of previous Act 35-49d**
T1	0.91	11.96	11.70	12.94	11.83	24.90	23.53	
T2	0.82	11.52	10.84	12.41	11.89	23.92	22.73	96.6
T3	0.73	11.42	10.16	12.31	11.11	23.72	21.27	93.6
T4	0.64	11.23	9.15	12.04	11.81	23.27	20.96	98.5
T5	0.55	10.86	8.08	11.50	12.09	22.36	20.17	96.2
T6	0.46	10.22	7.70	10.69	11.93	20.91	19.63	96.3

Correlation coefficients were calculated for a number of factors (Table 27). The good correlation (R = 0.99) between predicted and actual feed intake (35 – 49 days) confirms that the EFG model predicts values in the same direction as seen in practical trials, although predicted intake values were up to 400 g higher for the finisher period (Table 23, Figure 30).

Predicted feed conversion was higher than actual FCR owing to the higher feed intake and similar weight gains (Figure 29 - 31). Yet the correlation between actual and predicted feed conversion for 35 to 49 days was 0.998. As seen in paragraph 5.1, ("Simulation of literature data: Experiment One"), the correlation for carcass and breast meat percentages was low. Higher correlations were found for fat (g, Figure 33), fat (percentage, Figure 34) and energy intake (kcal, Figure 36 and Table 27). The correlation for breast meat percentage was poor (Table 27).

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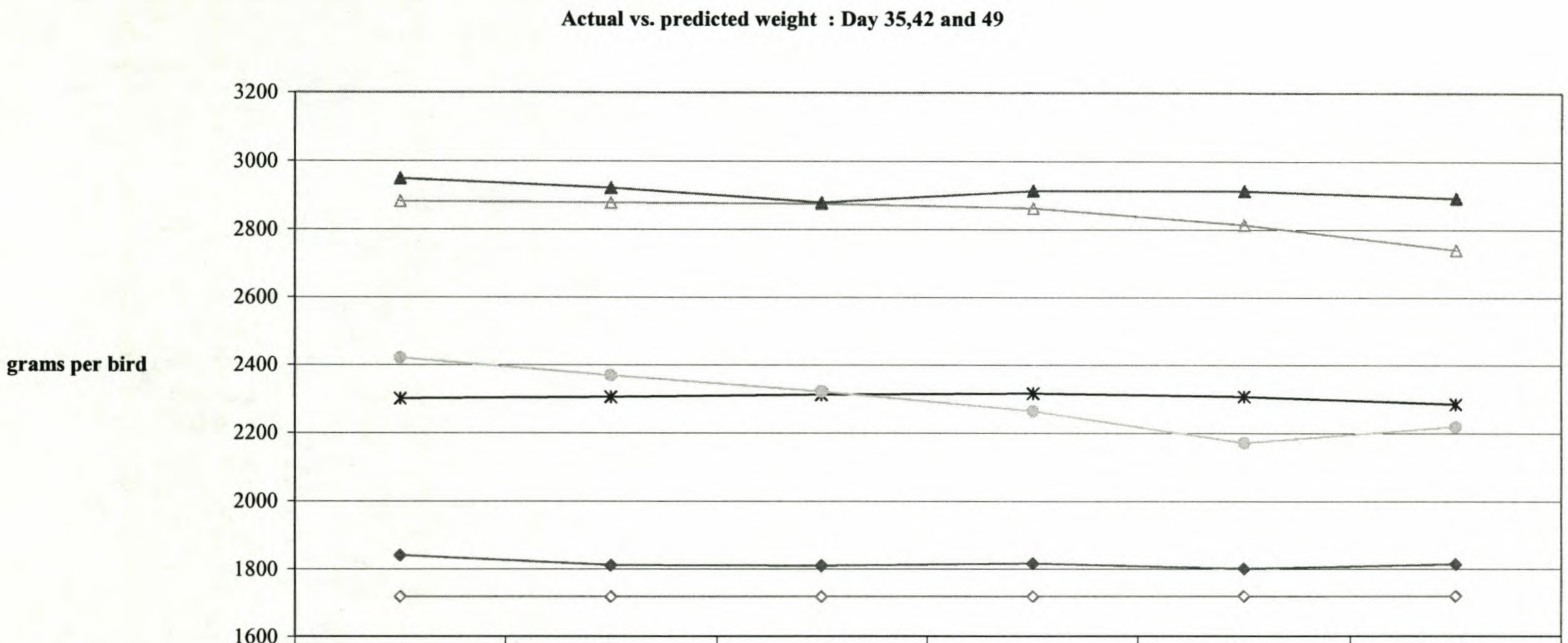
Table 27 Correlation coefficients for live weight, weight gain, FCR, carcass traits and energy intake between actual and EFG-predicted values for Experiment Two

	35 d	42 d	49 d	35-42 d	42-49 d	35-49 d
Weight		0.0934	0.4002			
Weight gain				0.1425	-0.7804	0.3307
Intake				0.9648	0.9904	0.9915
FCR				0.9752	0.9547	0.9978
Carcass percentage		-0.7389	-0.9232			
Fat (g)		0.9666	0.7778			
Fat (%)		0.9513	0.5523			
Breast meat (%)		0.2739	-0.4077			
Energy intake (kcal)						0.9237

Figures 28 to 36 illustrate the comparisons between actual published data (Leeson *et al.,* 1996a) and EFG predicted results.



	T1	T2	T3	T4	T5	T6
Pred 35d	1718	1718	1718	1718	1718	1718
Pred 42d	2299	2304	2311	2315	2306	2284
Act 42d	2420	2367	2320	2263	2170	2218
Pred 49d	2881	2877	2875	2862	2814	2740
Act 49d	2948	2921	2879	2913	2913	2892
Act 35d	1840	1811	1809	1815	1800	1814

Treatment

Figure 28 Actual vs. EFG-predicted weights (g/bird) at 35, 42 and 49 days of age where finisher diets differing in energy and amino acid concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

Actual weights (day 35) were all equal. The figure shows how the actual weight at 42 days decreased from T1 to T5, but increased at 49 days for T4 to T6.

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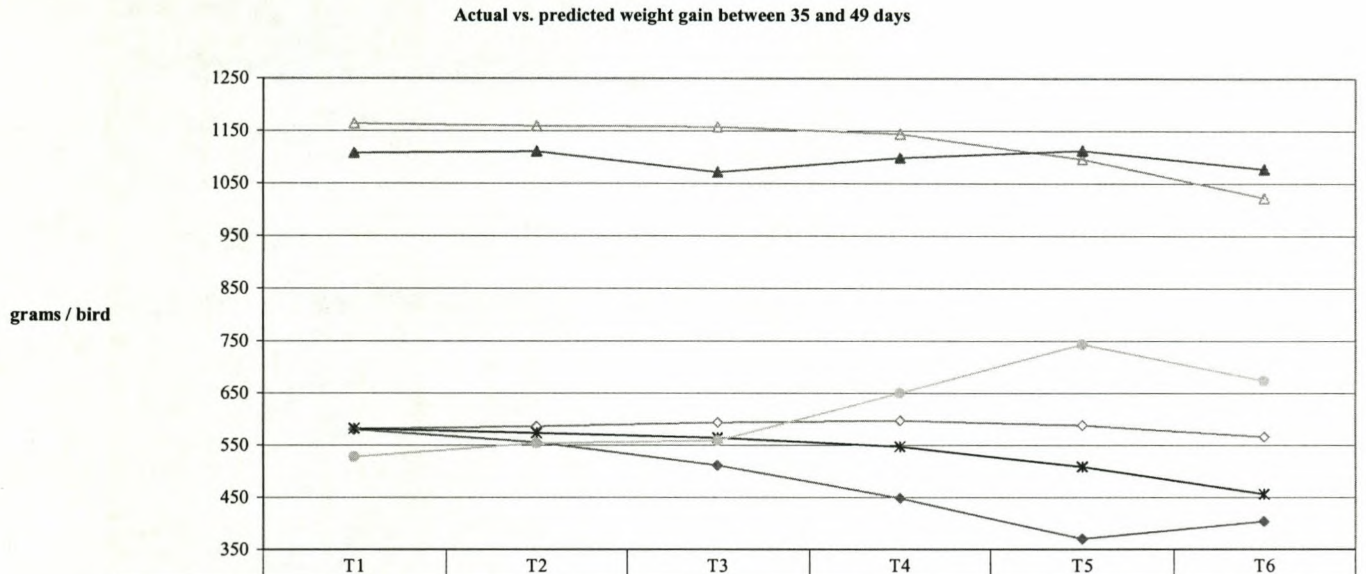

	T1	T2	T3	T4	T5	T6
Pred 35-42d	581	586	593	597	588	566
Act 35-42d	580	556	511	448	370	404
Pred 42-49d	582	573	564	547	508	456
Act 42-49d	528	554	559	650	743	674
Pred 35-49d	1163	1159	1157	1144	1096	1022
Act 35-49d	1107	1110	1071	1098	1112	1077

Treatment

Figure 29 Actual vs. EFG-predicted weights gain (g/bird) between 35-42, 42-49 and 35-49 days of age where finisher diets differing in energy and amino acid concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

Figure 29 shows the effect of the increase in weight gain (42 to 49 days) for T4 to T6, which is in contrast to predicted values.

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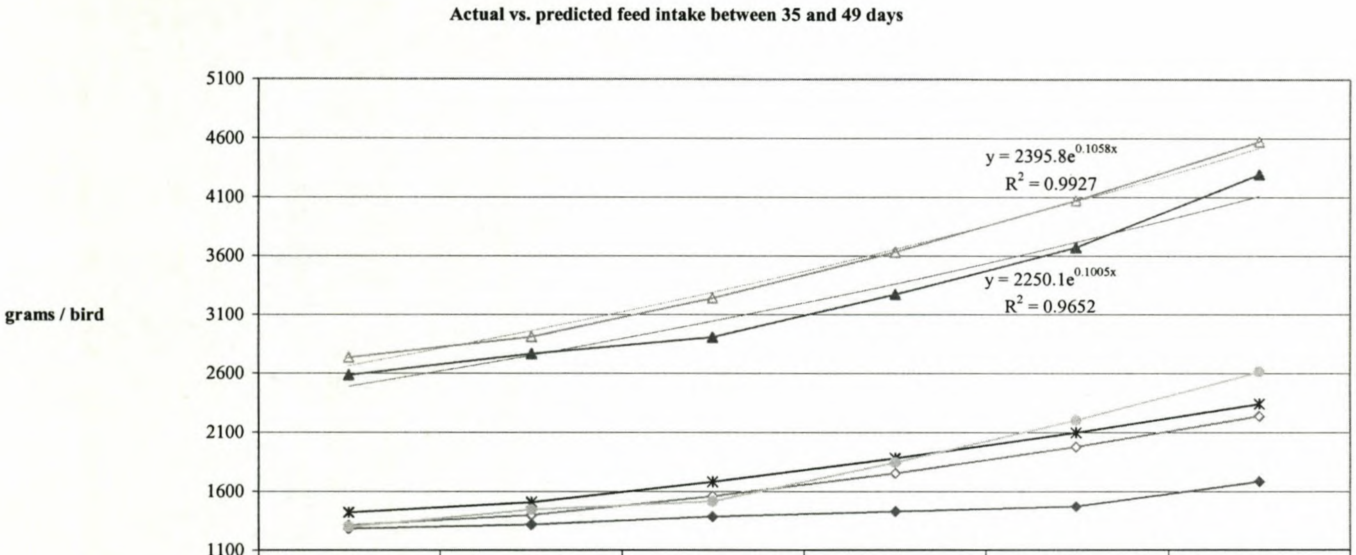
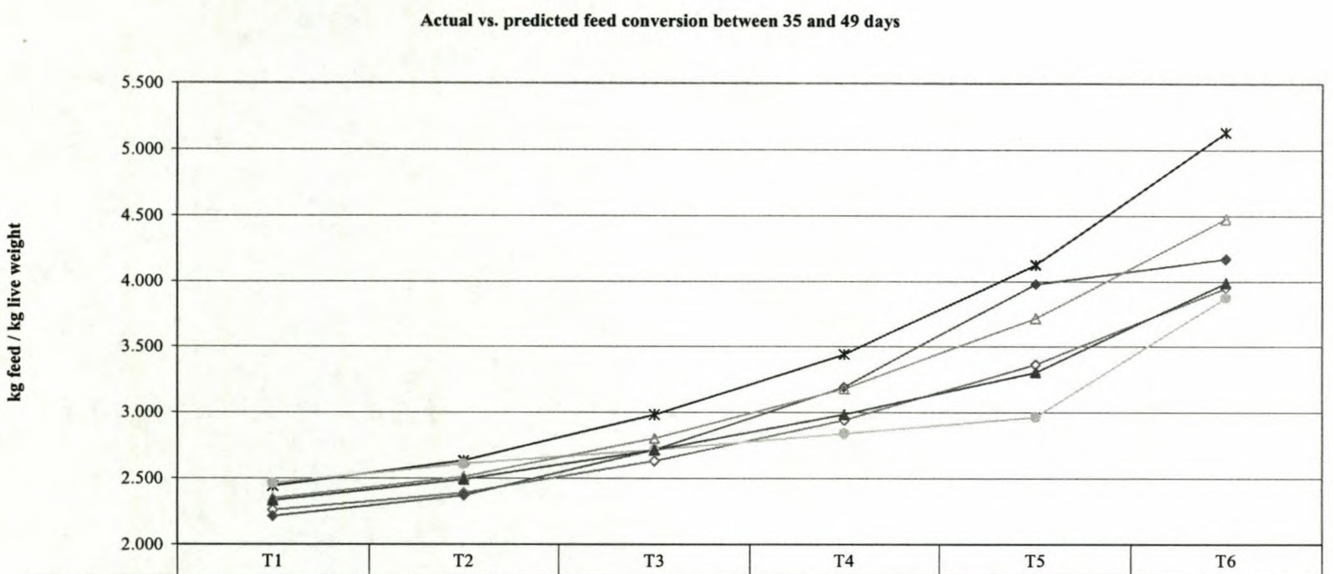


	T1	T2	T3	T4	T5	T6
Pred 35-42d	1313	1400	1559	1754	1977	2236
Act 35-42d	1284	1318	1387	1429	1472	1685
Pred 42-49d	1420	1508	1680	1881	2095	2340
Act 42-49d	1299	1445	1517	1844	2201	2610
Pred 35-49d	2733	2908	3239	3635	4072	4576
Act 35-49d	2583	2763	2904	3273	3673	4295

Treatment

Figure 30 Actual vs. EFG-predicted feed intake (g/bird) between 35-42, 42-49 and 35-49 days of age where finisher diets differing in energy and amino acid concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)



	T1	T2	T3	T4	T5	T6
Pred 35-42d	2.260	2.389	2.629	2.938	3.362	3.951
Act 35-42d	2.214	2.371	2.714	3.190	3.978	4.171
Pred 42-49d	2.440	2.632	2.979	3.439	4.124	5.132
Act 42-49d	2.460	2.608	2.714	2.837	2.962	3.872
Pred 35-49d	2.350	2.509	2.799	3.177	3.715	4.477
Act 35-49d	2.333	2.489	2.711	2.981	3.303	3.988

Treatment

Figure 31 Actual vs. EFG-predicted FCR (kg feed/ kg live weight) between 35-42, 42-49 and 35-49 days of age where finisher diets differing in energy and amino acid concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

Figure 31 shows how the reported increased in weight gain (T4 to T5) in the period 42 to 49 days improved FCR.

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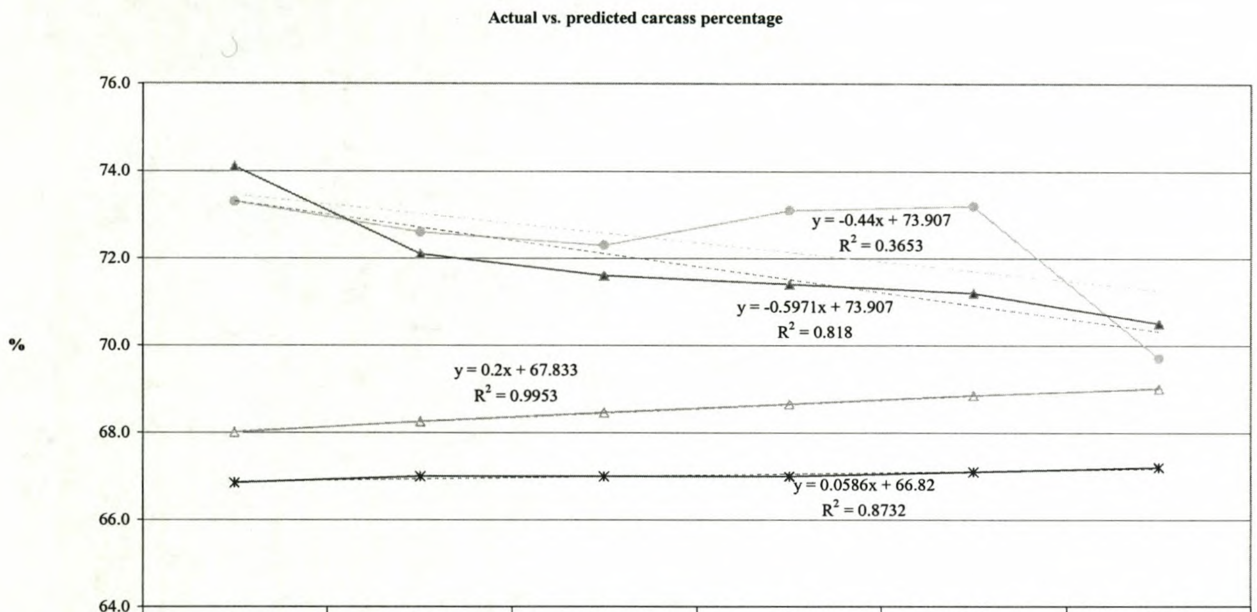

	T1	T2	T3	T4	T5	T6
Pred 42d	66.9	67.0	67.0	67.0	67.1	67.2
Act 42d	73.3	72.6	72.3	73.1	73.2	69.7
Pred 49d	68.0	68.3	68.5	68.7	68.9	69.0
Act 49d	74.1	72.1	71.6	71.4	71.2	70.5

Figure 32 Actual vs. EFG-predicted carcass percentage at 42 and 49 days of age where finisher diets differing in energy and amino acid concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.,* 1996b)

The negative correlation between actual and predicted carcass percentage is visible in Figure 32, as shown by the fitted regression lines. As mentioned previously, moisture loss could have been responsible for the inconsistent values, leading to the poor correlation.

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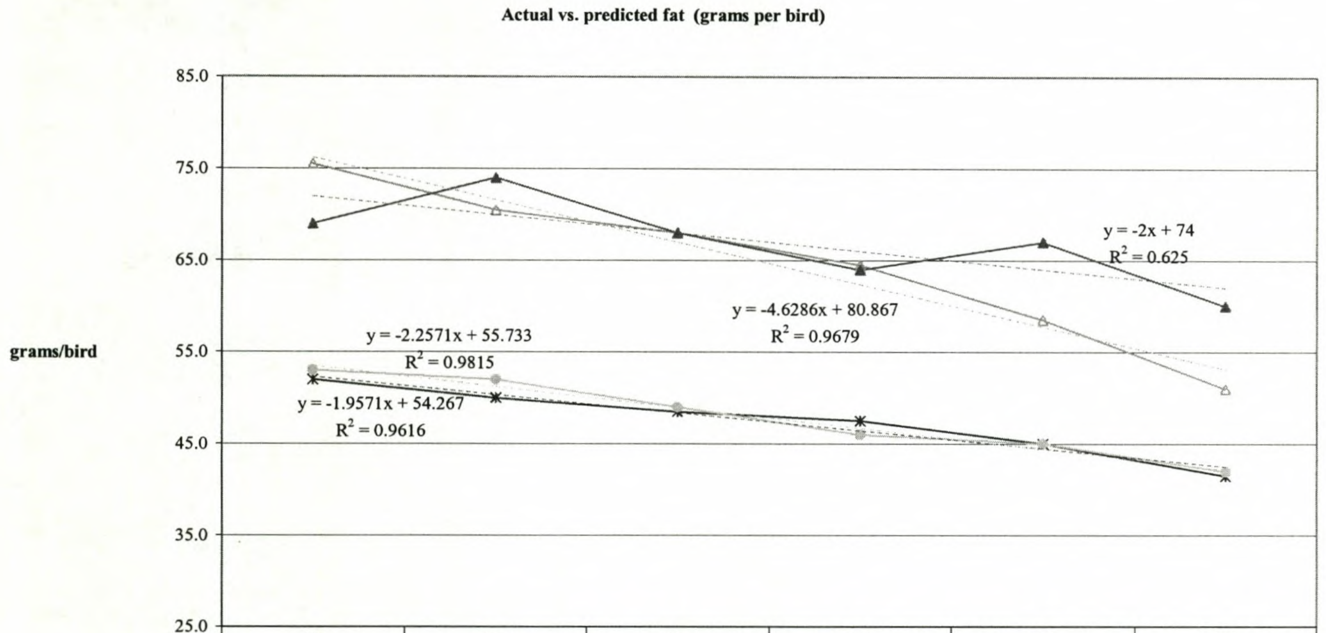

	T1	T2	T3	T4	T5	T6
Pred 42d	52.0	50.0	48.5	47.5	45.0	41.5
Act 42d	53.0	52.0	49.0	46.0	45.0	42.0
Pred 49d	75.5	70.5	68.0	64.5	58.5	51.0
Act 49d	69.0	74.0	68.0	64.0	67.0	60.0

Figure 33 Actual vs. EFG-predicted fat (g/bird) at 42 an 49 days of age where finisher diets differing in energy and amino acid concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.,* 1996a)

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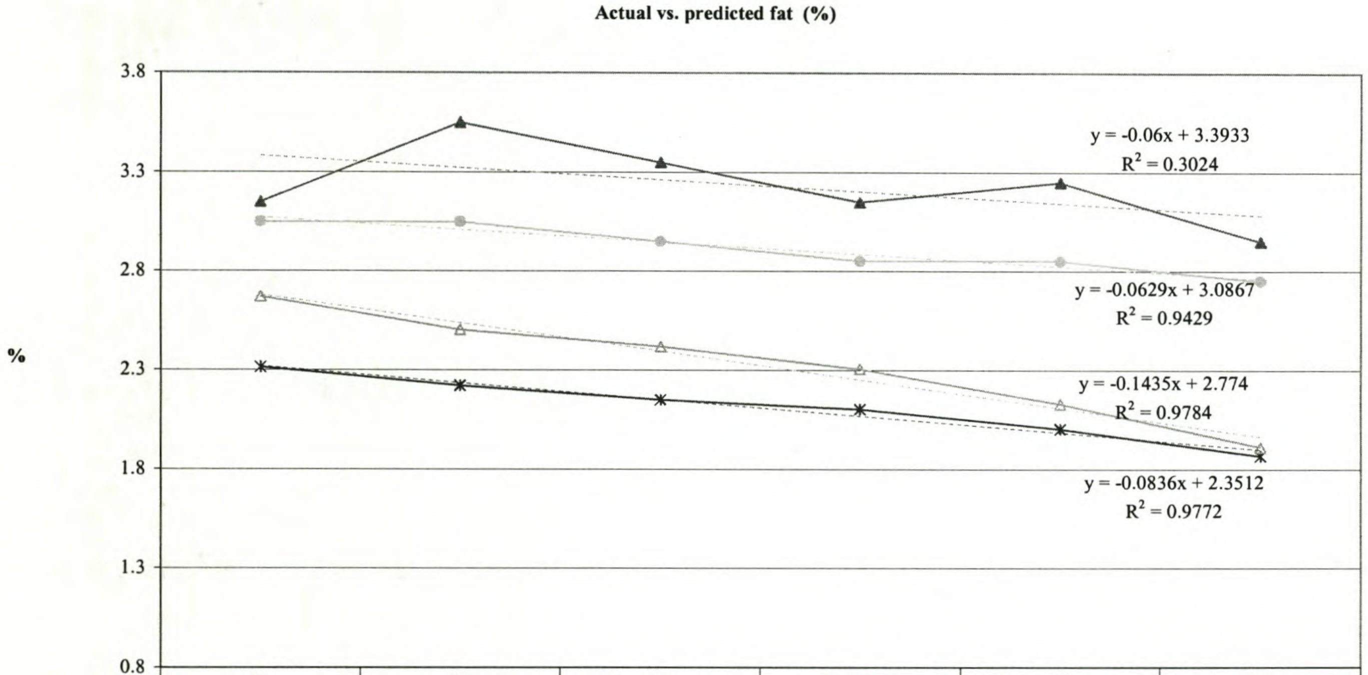

	T1	T2	T3	T4	T5	T6
Pred 42d	2.3	2.2	2.1	2.1	2.0	1.8
Act 42d	3.0	3.0	2.9	2.8	2.8	2.7
Pred 49d	2.6	2.5	2.4	2.3	2.1	1.9
Act 49d	3.1	3.5	3.3	3.1	3.2	2.9

Figure 34 Actual vs. EFG-predicted percentage fat at 42 and 49 days of age where finisher diets differing in energy and amino acid concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

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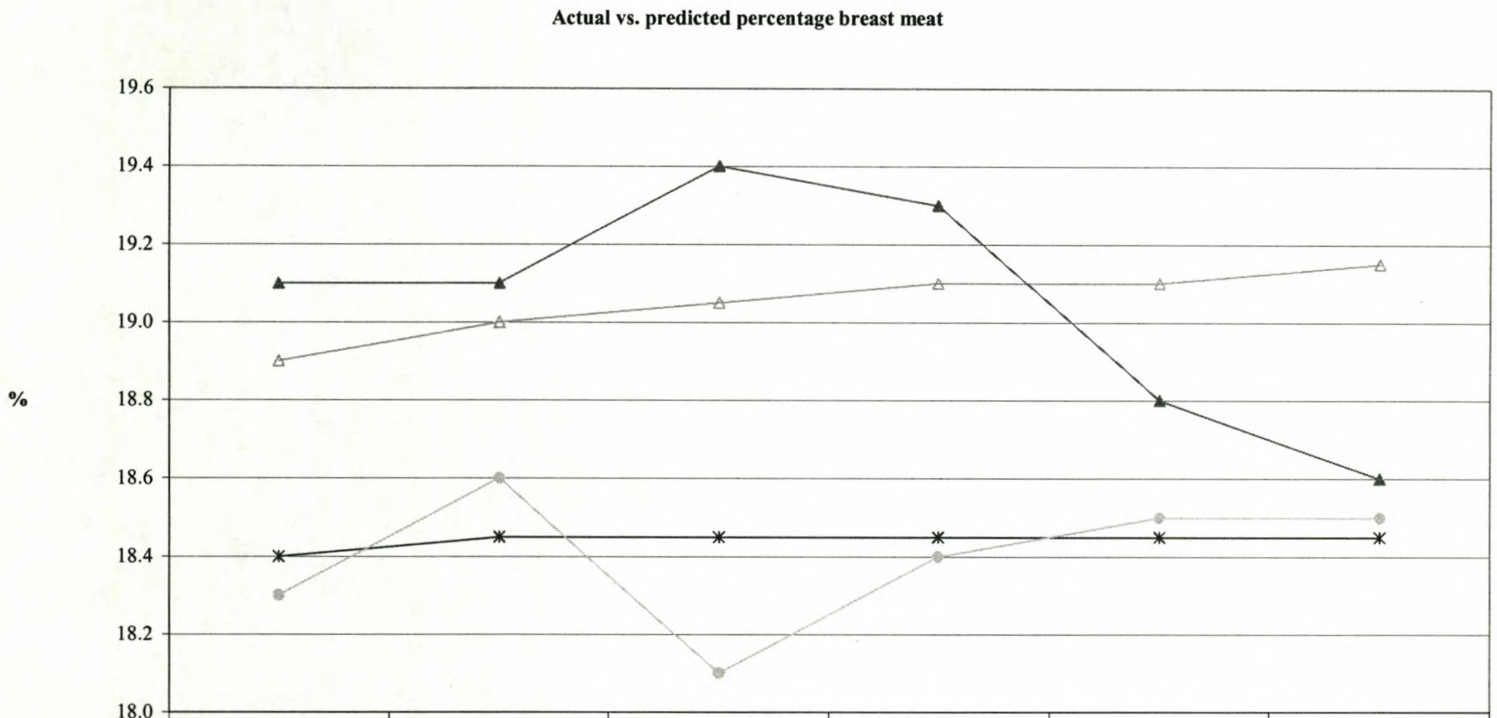

	T1	T2	T3	T4	T5	T6
Pred 42d	18.4	18.5	18.5	18.5	18.5	18.5
Act 42d	18.3	18.6	18.1	18.4	18.5	18.5
Pred 49d	18.9	19.0	19.1	19.1	19.1	19.2
Act 49d	19.1	19.1	19.4	19.3	18.8	18.6

Figure 35 Actual vs. EFG-predicted percentage breast meat at 42 and 49 days of age where finisher diets differing in energy and amino acid concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

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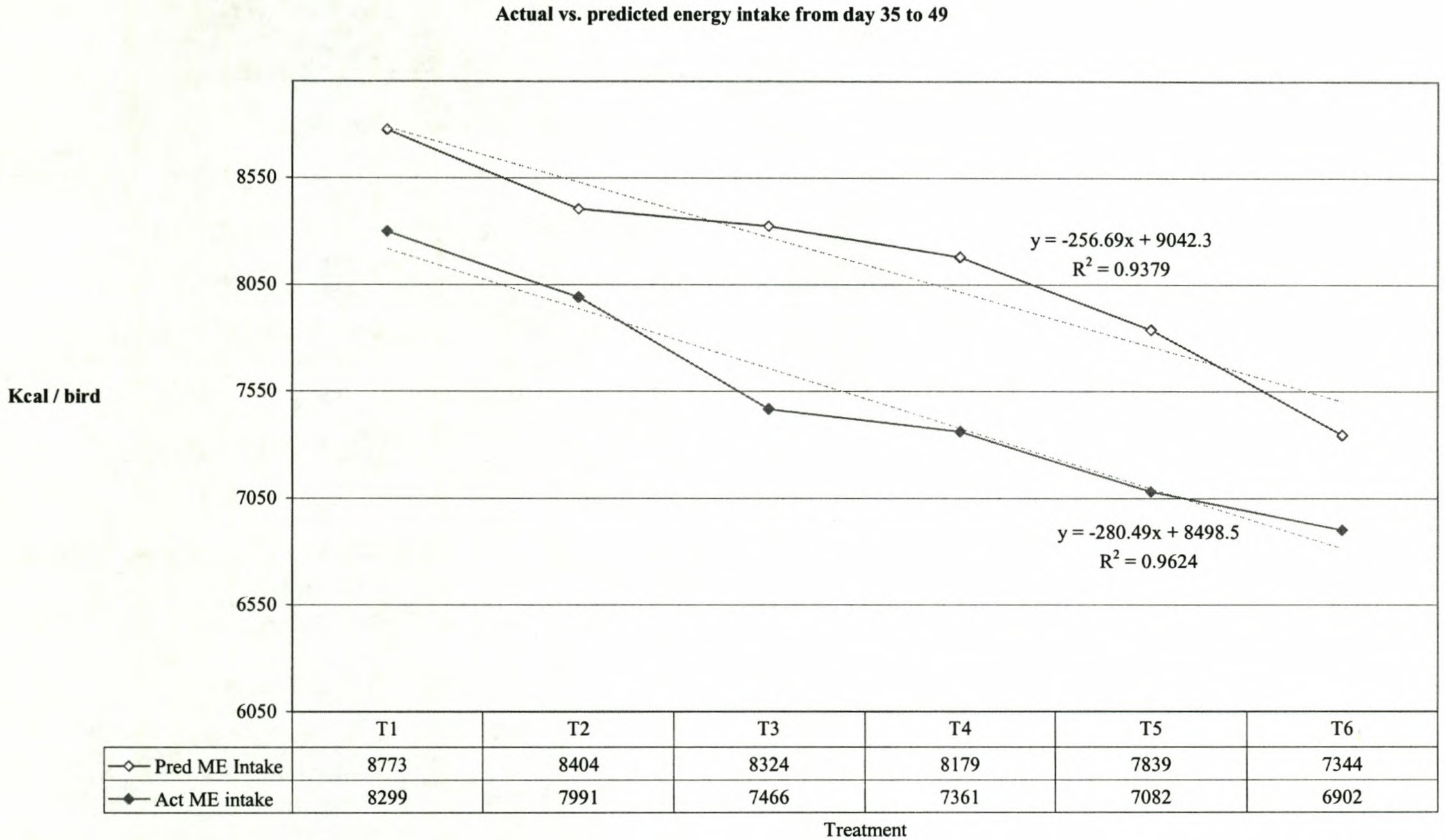

	T1	T2	T3	T4	T5	T6
Pred ME Intake	8773	8404	8324	8179	7839	7344
Act ME intake	8299	7991	7466	7361	7082	6902

Figure 36 Actual vs. EFG-predicted energy intake (MJ ME per bird) between 35-49 days of age where finisher diets differing in energy and amino acid concentration (T1 = high and T6 = low) were fed from 35 to 49 days of age (Leeson *et al.*, 1996a)

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5.3 CONCLUSIONS FOR LITERATURE SIMULATIONS

The discussion in this chapter shows how the model can be used to evaluate published data. The model predicted a logical and scientifically sound trend for all measured factors. Published data, however, created many questions, e.g. the pattern of weight gain in both sets of published data. The strong correlations between actual and predicted feed intake, energy intake and fat content of birds emphasise the strength of the model over a wide range of dietary specifications. Broilers possess a large capacity to adapt their feed intake to diet density. These birds could increased their actual feed intake by at least 65% as the finisher dietary density decreases from T1 to T6. When the increase in feed intake for data set no. one (where only energy concentration decreased) is compared to data set no. two (where both energy and amino acid concentration decreased), one notices an 804 and 1712 g actual increase in intake respectively. The fact that energy intake decreased in both trials, but amino acid intake actually increased for Trial One while it decreased in Trial Two, suggests that amino acid concentration in the diet and the DLys:ME plays a significant role in the control of feed intake under these extreme trial conditions.

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6. GENERAL DISCUSSION AND CONCLUSIONS

6.1 The EFG broiler model

From the discussion in paragraph 2.1 it can be seen that the EFG broiler model is based on a scientifically sound foundation. Predicting feather free and feather protein growth rate forms the corner stone of the model. Water, fat and ash growth can be calculated once the feather free protein growth rate is known. Energy and amino acid requirements are also derived from these values before feed intake can be calculated. These principles can be used to predict feed intake and production parameters if the nutrient specification, feeding program and environmental/management conditions are defined.

In simple terms, the response to different environmental conditions, stocking densities, temperatures, dietary specifications, feeding programs etcetera, can be simulated if the protein growth rate for that condition is known. Predicting feed intake accurately for these conditions is critical for accurate predictions.

The model not only predicts production and carcass results but also calculates profitability, whether birds are sold live, dressed or sold as portions. Many producers pay bonuses to employees based on PEF. This results in conflict between the owner measuring profit and managers measuring production results. As seen in Trial One, the best PEF does not always relate to the best profitability. The integration of the EFG broiler model with a least cost feed formulation system (Win Feed) is a major step ahead to optimise profit. Because of the time being saved in finding the correct dietary specification for optimising profit, reaction time to changing market conditions can be minimized.

Some factors are still difficult to simulate, e.g. the response of birds to micotoxins, amino acid interactions, metabolic disorders and the response to infectious diseases. The rate at which birds adapt their feed intake to new dietary specifications may also lead to differences between actual and predicted data.

It can be concluded that the EFG broiler model is based on sound principles. The model is comprehensive and can be used for a wide range of environmental/management conditions as well as dietary specifications. This is a distinct advantage to common research where results are to a large extent tied to the environmental conditions and diets used for the trial. The nutritionist can use the model with confidence to assist in practical feed formulation. The actual strength of the model lies in the time and money being saved compared to practical trials.

6.2 Simulation of Trial One and Two

6.2.1 Actual data

In Trial One the amino acid density decreased with 5% between treatments in the whole range of Pre-starter to Finisher diets, from treatment A (high) to treatment C (low). Actual body weight at 35 days decreased with 13 g while feed intake increased with 35 g from A to C. Although these differences were not significant ($P<0.05$), the trends were clear. (see Figure 7 – 9)

In Trial Two, only the finisher diet's amino acid density decreased on average 6% from A to D. In Trial Two body weight at 35 days decreased ($P<0.05$) with 64 g from A to D, but feed intake only increased numerically from A to B (32 g), with small changes (B-C: +8 g, C-D: -3 g) between B and D. (see Table 7 and 13)

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6.2.2 Predicted data

In contrast to actual data from the two trials mentioned above, the EFG-predicted 35 day weights in both Trail One and Two did not differ significantly between treatments. (see Table 7 and 13) Predicted feed intake for Trial One, where diet densities differed between treatments from day one, followed the same increased trend (+85 g from A to C) as for actual data (+35 g from A to C). (see Table 7 and Figure 9) Predicted feed intake for Trial Two, where diet densities differed only in the finisher period, also increased as the dietary specification decreased from A to D. These differences were smaller (+19 g from A-D) compared to Trial One (+85 g from A to C). As mentioned in the previous paragraph, actual feed intakes increased with 32 g from A to B, then with 8 g from B to C and then decreased with 3 g from C to D.

6.2.3 The difference between actual and predicted data

In both Trial One and Trial Two the actual feed intake was higher than the predicted values (average 110 g and 174 g respectively), while the actual weights were also higher than predicted values (average 77g for both trials). Calculating this feed conversion gives 1.43 and 2.26 respectively. The higher actual feed intake therefore explains to a large extent the difference in live weight at 35 days.

It was interesting to note that the difference between actual and predicted live weight at 35 days were higher for the high density diets in Trial One (86 g vs. 72 g for treatment A and C respectively, see Table 7) as well as in Trail Two (112 g vs. 47 g for treatment A and D respectively). In both Trial One and Two the better actual weights were obtained where the DLys (as percentage) : ME (Mkal/kg) in the finisher diets was higher than 30.

The main difference between predicted and actual results for both Trial One and Two was the response to body weight. The model predicted a steady increase in feed intake to compensate for the lower dietary specifications while body weight did not change significantly. This increase in feed intake was enough to maintain body weight.

Trial birds also increase feed intake as dietary amino acid density decreases, but this compensation was too low to maintain body weight compared to the control diet. The trial birds sacrificed ±4 g and ±20 g in body weight between treatments in Trial One and Two respectively. The difference of 4 g vs. 20 g in the two trials, may indicate that the birds find it easier to compensate when they have time to adapt to the specification.

There is evidence in the literature that birds need seven days to adapt their feed intake to a lower feed specification (Leeson *et al.*, 1996a). It can be speculated that the trial birds started to loose body weight due to a lower amino acid intake in this period. The model seems to adapt feed intake immediately after a change in diet specification.

6.3 Simulation of literature data (Leeson *et al.,* 1996a)

6.3.1 Feed intake

Accurate prediction of feed intake is one of the most important calculations of the model. The comparison of predicted and actual data for literature simulation One and Two (see paragraph 5.1 and 5.2) shows interesting results.

In Simulation One where only energy concentration of the diets decreased from T1 to T6, the predicted increase in feed intake (T6 less T1, 35 to 49 days) was 404 g (+14.8%) while it was 804 g (30.7%) for actual values. (see Table 16) In this period, actual energy intake decreased with ±5% between treatments while actual digestible lysine intake increased with ±5% between treatments. The latter was because only amino acid concentration was constant in all treatments and feed intake increased. (see Table 18 and 19)

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In Simulation Two where energy and amino acid concentration decreased from T1 to T6, actual energy as well as digestible lysine intake decreased by ±4% between treatments from 35 to 49 days. (see Table 25 and 26) The actual and predicted increase in intake (T6 less T1, 35 to 49 days) was 1712 g (66.2%) and 1843 g (67.0%). (See able 23) Compared to values given above for experiment one (804 g and 404 g respectively), there was a significant increase in feed intake for both actual and predicted values in experiment two. The percentage increase in intake (g per bird, 35 to 49 days) for experiment two was the same for actual and predicted values (66.2 and 67.0%), but not for experiment one where the corresponding values were 30.7 and 14.8%. These differences indicate the importance of amino acid density as well as the DLys:ME in the accuracy of predicting feed intake.

6.3.2 Amino acid to energy ratio

When actual and predicted intakes are compared between 35 and 49 days in Simulation One, predicted intakes are 110 g higher for T1 but 290 g lower for T6 (Table 16). Table 14 shows that the DLys (%) : ME (Mkal) increases from 28.3% in T1 to 46.7% in T6.

When actual and predicted intakes are compared between 35 and 49 days in Simulation Two, predicted intakes for all treatments are higher (150 to 400 g) than actual intakes. (see Table 23) Table 21 shows that, in contrast to Simulation One, the DLys (%) : ME (Mkal) stays constant at ±28.5%. These figures, therefore, also suggests that the DLys:ME ratio plays a role in the way the model predicts feed intake and therefore production parameters.

6.3.3 Summary of conclusions

The simulation on literature data lead to the following conclusions:

1) Broilers posses the capacity to increase their feed intake with at least 65% should finisher diets with lower amino acid and energy concentrations be supplied. If only the energy concentration of finisher diets were decreased, the increase in feed intake will be around 30%. (see Table 16 and 23)
2) The accurate prediction of feed intake from the given dietary specification has a major influence on the accuracy of the prediction of broiler performance.
3) Amino acid density and DLys:ME ratio plays a significant role in the control and prediction of feed intake.

6.3 The use of the EFG model for evaluation

The arguments described in paragraph 5.1.and 5.2 demonstrated how the model could be used to evaluate published as well as own trial data. The increased weight gain between treatments as published by Leeson *et al.*, 1996a was difficult to explain when feed and nutrient intakes were calculated and compared to the EFG predicted response. In contrast to published data, the model predicted logical trends for carcass characteristics vs. nutrient specifications.

6.4 Correlation coefficients

Good correlations (R>90) between actual and predicted values were calculated for feed intake (35 days, Trial One and Two), for feed and ME intake (49 days, Literature Simulation One and Two) and for carcass fat (49 days, Literature Simulation One). Poor correlations between actual and predicted values were calculated for weight in all trails. The reason seems to be that the model adjusted feed intake to compensate for the lower dietary specification. This increase in feed intake was enough to maintain body weight for the predicted response, but trial birds lost weight in spite of an increased feed intake. As mentioned above, the reported weights in Leeson's trials were difficult to explain and resulted in poor correlations for weight. Published carcass data generally did not follow the logical EFG predicted trends. It can be speculated that moisture loss during analyses could have skewed published data. It is therefore concluded that within the scope of this document, the EFG model predicted carcass characteristic more accurate than the published data.

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7. APPENDICES

Appendix 1 EFG broiler model parameters: Broiler Trial One

Growth constraints					**Growth Parameters (male)**		
Age	Males	Females	Temperature	Humidity	Mature empty body weight (kg)	6.500	
1	0.85	1.00	31.0	60	Mature fat content (%)	14.000	
2	0.85	1.00	31.0	60	Rate of maturing (/d)	0.041	
3	0.88	1.00	31.0	60	Rate of feathering (/d)	normal	
4	0.91	1.00	30.5	60	Feather sexable?	yes	
5	0.93	1.00	30.0	60			
6	0.96	1.00	29.5	60			
7	0.99	1.00	29.0	60			
8	1.00	1.00	28.5	60	**Derived Parameters**	**Male**	**Female**
9	1.00	1.00	28.0	60	Mature protein (kg)	1.196	0.835
10	1.00	1.00	27.5	60	Mature LP ratio	0.761	1.522
11	1.00	1.00	27.0	60	Mature fat (kg)	0.910	1.271
12	1.00	1.00	26.5	60	Mature water (kg)	3.850	2.689
13	1.00	1.00	26.0	60	Mature ash (kg)	0.263	0.184
14	1.00	1.00	25.5	60	Mature feathers (kg)	0.282	0.222
15	1.00	1.00	25.0	60	B (body, per day)	0.041	0.042
16	1.00	1.00	24.5	60	B (feathers, per day)	0.056	0.060
17	1.00	1.00	24.0	60	b (fat allometry)	0.409	0.652
18	1.00	1.00	23.5	60			
19	1.00	1.00	23.0	60			
20	1.00	1.00	22.5	60			
21	1.00	1.00	22.0	60			
22	1.00	1.00	21.5	60			
23	1.00	1.00	21.0	60			
24	1.00	1.00	20.5	60			
25	1.00	1.00	20.0	60			
26	1.00	1.00	20.0	60			
27	1.00	1.00	20.0	60			
28	1.00	1.00	20.0	60			
29	1.00	0.99	20.0	60			
30	1.00	0.98	20.0	60			
31	1.00	0.96	20.0	60			
32	1.00	0.95	20.0	60			
33	1.00	0.94	20.0	60			
34	1.00	0.93	20.0	60			
35	1.00	0.93	20.0	60			
36	1.00	0.92	20.0	60			
37	1.00	0.92	20.0	60			
38 to 42	1.00	0.91	20.0	60			

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Appendix 2 EFG broiler model parameters: Broiler Trial Two

Growth constraints							
Age	Males	Females	Temperature	Humidity			
1	0.85	0.85	31.0	60	**Growth Parameters (male)**		
2	0.85	0.85	31.0	60	Mature empty body weight (kg)	6.500	
3	0.88	0.88	31.0	60	Mature fat content (%)	14.000	
4	0.91	0.91	30.5	60	Rate of maturing (/d)	0.041	
5	0.93	0.93	30.0	60	Rate of feathering (/d)	normal	
6	0.96	0.96	29.5	60	Feather sexable?	yes	
7	0.99	0.99	29.0	60			
8	1.00	1.00	28.5	60			
9	1.00	1.00	28.0	60	**Derived Parameters**	**Male**	**Female**
10	1.00	1.00	27.5	60	Mature protein (kg)	1.196	0.835
11	1.00	1.00	27.0	60	Mature LP ratio	0.761	1.522
12	1.00	1.00	26.5	60	Mature fat (kg)	0.910	1.271
13	1.00	1.00	26.0	60	Mature water (kg)	3.850	2.689
14	1.00	1.00	25.5	60	Mature ash (kg)	0.263	0.184
15	1.00	1.00	25.0	60	Mature feathers (kg)	0.282	0.222
16	1.00	1.00	24.5	60	B (body, per day)	0.041	0.042
17	1.00	1.00	24.0	60	B (feathers, per day)	0.056	0.060
18	1.00	1.00	23.5	60	b (fat allometry)	0.409	0.652
19	1.00	1.00	23.0	60			
20	1.00	1.00	22.5	60			
21	1.00	1.00	22.0	60			
22	1.00	1.00	21.5	60			
23	1.00	1.00	21.0	60			
24	1.00	1.00	20.5	60			
25	1.00	1.00	20.0	60			
26	1.00	1.00	20.0	60			
27	1.00	1.00	20.0	60			
28	1.00	1.00	20.0	60			
29	1.00	1.00	20.0	60			
30	1.00	1.00	20.0	60			
31	1.00	1.00	20.0	60			
32	1.00	1.00	20.0	60			
33	1.00	1.00	20.0	60			
34	1.00	1.00	20.0	60			
35	1.00	1.00	20.0	60			
36	1.00	1.00	20.0	60			
37	1.00	1.00	20.0	60			
38 to 42days	1.00	1.00	20.0	60			

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